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APRIL • 1940

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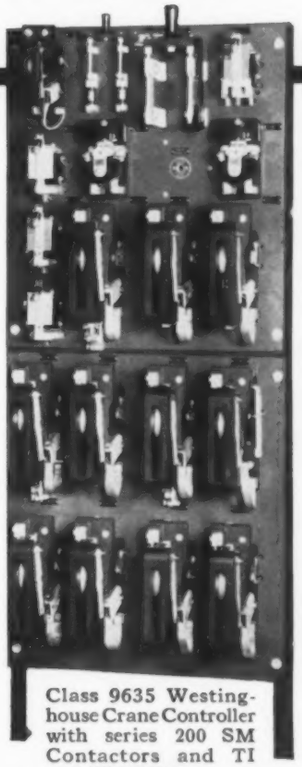

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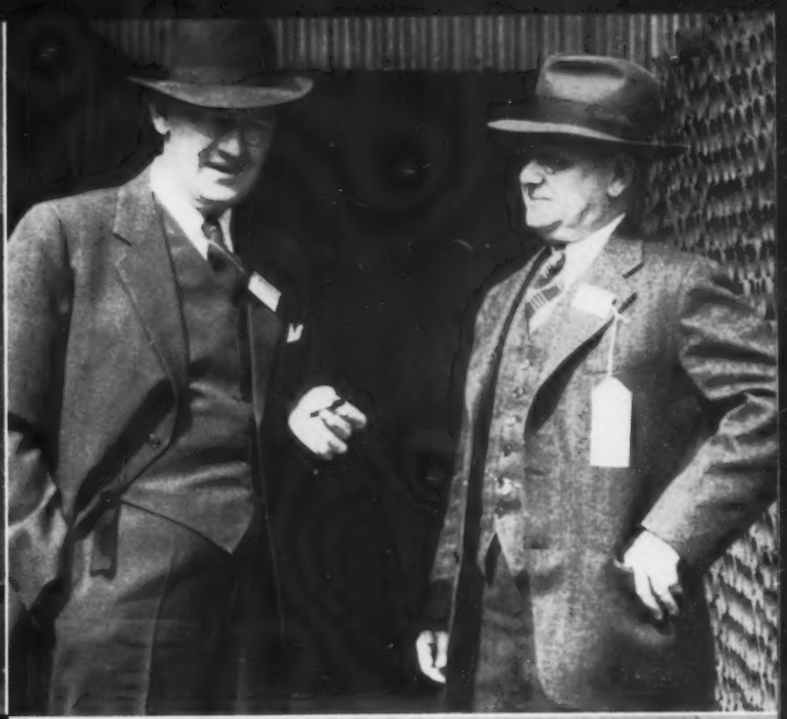
REVIEW
OF
Annual Spring Conference
HOTEL NETHERLAND PLAZA
CINCINNATI, OHIO
APRIL 1 and 2, 1940

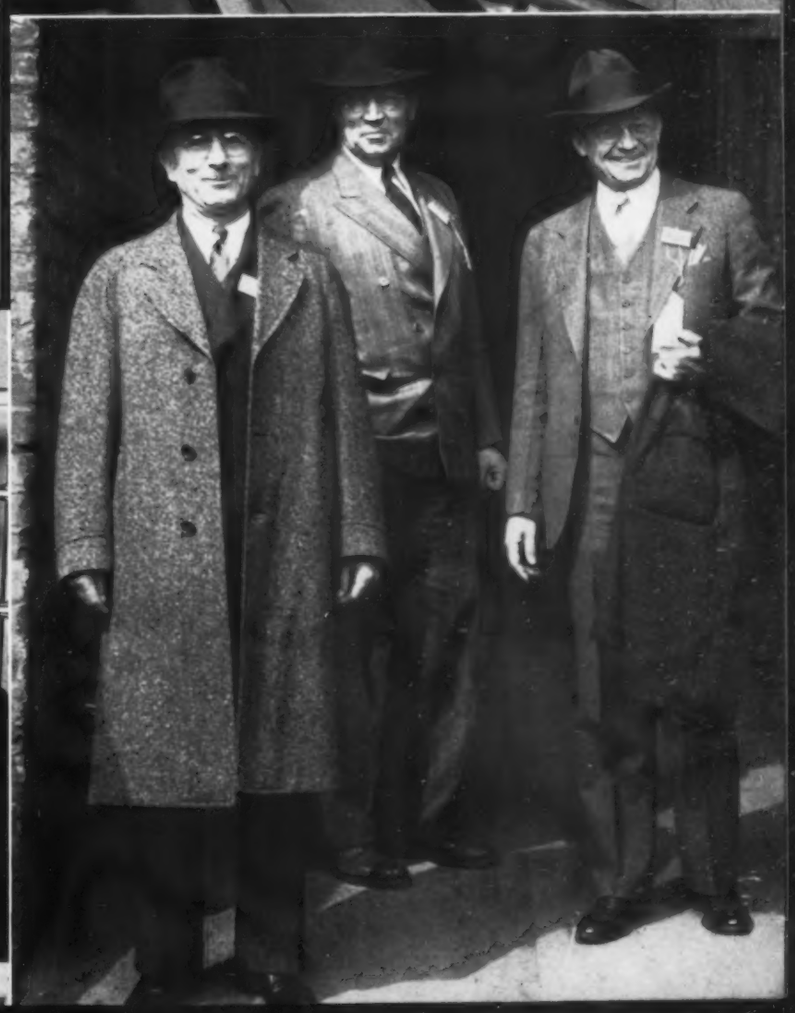
To the more than 500 steel plant engineers and operators who registered at the 1940 Spring Conference of the Association of Iron and Steel Engineers, this meeting brought a vivid picture of the importance of the Cincinnati district as a factor in our national economic picture. Representing the first visit of the Association to the district, the meeting carried a characteristically full program. Early arrivals, among whom were V. A. Menaglia *(left)*, B. J. Ballard, and H. R. Zimmerman *(left, center)*, found their time fully planned for the duration of the Conference. At left, bottom, are shown F. Gordon Ricker, J. H. Vohr, A. J. Jennings, and LeRoy Brooks, as they awaited the first technical session, which was presided over by H. G. R. Bennett and W. A. Perry *(right, center)*. This session included papers by D. A. McArthur and A. F. Kenyon *(right, bottom)*.



Also on the first technical session was a joint paper by H. W. Poole and E. S. Murrah, who are shown above with J. J. Huether.

Monday afternoon was devoted to an inspection trip through the plants of the Andrews Steel Company in Newport, Kentucky. Over 270 members and guests made this trip and found much of interest in these plants, which have remained in the ownership and management of the Andrews family since the founding of the company in 1885. Among the interested spectators on this trip were T. E. Hughes and L. F. Coffin *(upper right)*, J. H. Vohr and C. L. McGranahan *(right, center)*, and D. O. Fisher, F. W. Robertson, and E. S. Sawtelle *(right, bottom)*.

Immediately below are shown C. R. Hook, speaker at the informal dinner Monday evening, and President J. A. Clauss.

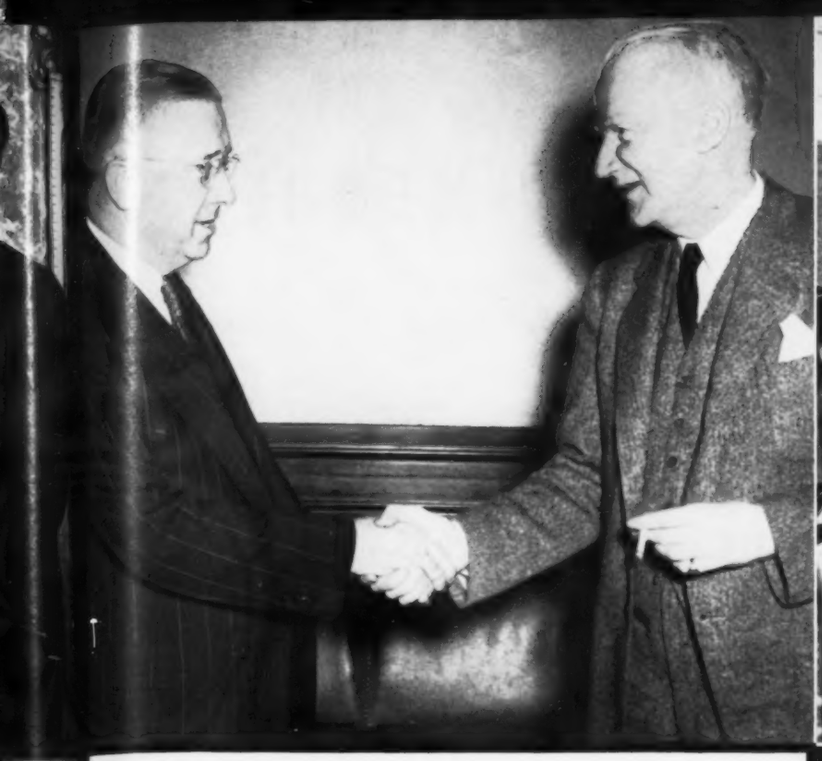


In his talk, Mr. Hook stressed the importance of the incentives to the individual to work and save, as offered by private enterprise. Loss or basic alteration of this factor removes all hope for continued progress and a higher standard of living. Referring to the lack of cooperative effort in the early days of industry, Mr. Hook stated that both had to learn that cooperation is profitable to all, and that when industry finally realized that an exchange of ideas and technical information, as well as good industrial relations, were beneficial, an era of unprecedented progress was born.

Much of the success of the Conference may be attributed to the efforts of the local committee under the chairmanship of M. M. MacDonald, shown upper left with J. B. Andrews, Jr.

Following the dinner a technical session was held, at which papers were presented by L. F. Reinartz and G. D. Tranter *(upper right)*.

Tuesday was devoted to an inspection of the Hamilton and Middletown plants of American Rolling Mill Company. Among the 400 participants was J. A. Rock, shown lower left with J. S. Ferguson. Luncheon was served at Middletown through the fine hospitality of American Rolling Mill Company, at which time G. M. Verity, shown lower right with President J. A. Clauss, addressed the assemblage. Mr. Verity emphasized the necessity for managerial creative ability, which is in a large part the responsibility of the engineer. He further gave two points of great importance to management: the environment around the plant and in the community in which workmen live, and the creation of the proper spirit in the men so that they will contribute their best.



The exchange of greetings between F. E. Flynn and J. B. Tytus *(upper left)* brought together two pioneers in the field of continuous strip rolling. Both of these men were engaged in the early work incident to the evolution of the modern continuous wide strip mill, and have contributed many developments to its progress.

At top, right, is shown part of the crowd entering the new Armco research laboratory. Among this group were H. L. Shepard, L. V. Black, J. M. Kelly and M. B. Farrar *(right)*, R. S. Shoemaker and C. C. Pecu *(bottom, left)*, and L. F. Coffin and A. W. Steed *(bottom, right)*.

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Details of Design

NO. 5 BLAST FURNACE *Inland Steel Co.*

By H. W. JOHNSON

Superintendent Blast Furnaces

INLAND STEEL COMPANY

INDIANA HARBOR, INDIANA

Presented before A. I. S. E. Annual Convention, Pittsburgh, Pennsylvania, Sept. 26-29, 1939

▲ We have been asked to present to you a discussion of the design or operation of Inland's No. 5 blast furnace. During the past few years, some excellent papers have been presented before this Association on modern blast furnace design and construction, blowing in, and operation. Since all blast furnaces are built alike in their essentials, and operated alike, it is obvious that a discussion of the general design or initial operation of No. 5 furnace would give no new light on the subject. But furnaces, though alike in essentials, still differ in details of design. Some portions of the design of No. 5 are different from the usual arrangements on furnaces of this size. This paper will discuss some of the experience and experiments that led us to select certain plans, and will furnish material from operation for judging their effectiveness.

Four areas of construction will be discussed. First is the equipment provided to prepare the coke and charge it into the furnace. Next are the factors in design which determine the radial distribution of the gases in the stock column. The third is the height of the furnace, and the fourth the provisions made for heating and controlling the blast.

COKE HANDLING

Coke charged into the furnace has two principal functions. It furnishes most of the heat required for the process and provides much of the voids in the stock column necessary for gas flow. The capacity to furnish heat can be determined by chemical analysis and will not be discussed here. What we are concerned with is its capacity to provide the proper voids in the stock column.

In Lake Superior practice, coke is the material largest in size and occupies 55 to 65 per cent of the volume of materials charged into the furnace. It is obvious, therefore, that since it occupies most of the volume and is the largest in size, it provides a large proportion of the voids in the furnace which are necessary for the gas flow. The location of voids in the stock column determines where the gas will flow, so the more we can make the coke assist in providing the proper voids across the entire stock column to promote gas-solid contact, the better heating and reduction of ore and the more efficient the operation.

Unfortunately, coke is a brittle product, and the size is easily reduced by handling. The problem, therefore, is to see that the coke reaches the stock column in the best possible size to perform its function of providing voids. It is important that coke be uniform, not only across the layer, but also from one layer to the next, since uniformity of operation is essential in blast furnaces. So coke-handling equipment should enable the operator to keep each charge similar to the one before.

COKE BREAKAGE

The fact that coke is brittle is so generally accepted that tests are commonly made to measure the amount of breakage. This is most generally done by the shatter test, which measures the variations in the degree of breaking of different cokes.

Ordinarily when examining the results of a shatter test, we are conscious of the "shatter index," or a similar figure which represents some physical quality of the coke. Now, instead of referring to the index we will examine some typical shatter tests to determine how much reduction in size has taken place, bearing in mind that the four drops of six feet in the shatter test approximates the handling that coke receives when dropped from car to bin, bin to skip, skip to small bell, small bell to big bell, and then into the furnace.

These shatter tests were taken on samples of coke made from 30 per cent Pocahontas and 70 per cent high volatile Eastern Kentucky coal, coked in a 16 in. oven

for 17 hours. The results shown are averages of the number of tests indicated:

TABLE 1

Results of Typical Shatter Tests Showing Amount of Breakage

Original size of sample	+4″	−4″+3″	−3″+2″
Number of samples	4	4	5
Size after shatter test:			
+4 in.	21.3	....	....
+3 in.	23.0	39.0	....
+2 in.	33.0	35.7	61.7
+1¼ in.	15.8	18.3	30.2
−1¼ in.	7.0	6.8	7.9
Original average size	4.5″	3.5″	2.5″
Average size after test	2.89″	2.60″	2.08″
Per cent reduction	35.9	25.7	16.8

We note a decided reduction in size of coke in all cases, but most pronounced for the largest size. In all cases, some of the original coke remained intact and some was broken enough to pass through a 1¼ in. screen. It can be concluded that despite all care in sizing coke before charging, by the time it reaches the furnace stock line much small coke has been produced. The increase in the range of sizes results in undesirable segregation in the furnace.

The amount of breakage which occurs between the screening station at the coke plant and the blast furnace skip varies considerably, depending upon the physical quality of the coke and the method of handling and preparation. We found that the average diameter of the pieces of coke was decreased as much as 25 per cent in the former system of handling between these two points and that 9 per cent of minus 1⅛ in. coke was produced. The present system is to screen blast furnace coke over a 1⅛ in. screen at the coke plant; yet after transfer to a conveyor belt and then to the blast furnace highline, loading through a chute directly into cars, and dumping into bins, we find that 4 to 5 per cent of minus 1⅛ in. coke is produced. The system was designed to prevent coke breakage, but in spite of very careful operation, this amount of breakage cannot be decreased.

The amount of damage that has been done cannot be stated on any financial basis because of the many variables. In general, coke decreases in value with decrease in size, and so every effort should be made to avoid breakage and the production of fines.

THE EFFECT OF FINE COKE ON FURNACE OPERATION

Example 1. The damaging effect of charging these fines into the blast furnace is generally accepted. The following is quoted from Mott and Wheeler:[1] "A lower limit to the size for coke to be of value in the blast furnace is universally admitted. It is a matter of economic importance to decide what the lower limit should be. At one blast furnace plant, coke pieces less than 1¼ in. were screened out between the hoppers and the skips. It was found that the output of the furnaces was greater, whilst the gross amount of coke used per ton of pig did not increase. In other words, the coke screened out (and used for other purposes) performed no useful function in the blast furnace, but reduced its output. The records (E. C. Evans, *Fuel*, 1927, 6–245) are given in Table 2.

TABLE 2

The Effect of Removing 1¼ in. Coke in Blast Furnace Practice

Period	Coke arriving at works, lb. per ton of pig	Coke charged, lb. per ton of pig	Breeze through 1¼ in. screened out, lb.	Total burden	Average make, tons per week	Maximum make, tons per week
1921	3180	3180	Nil	7560	1150	1202
1925	3120	2930	190	7570	1380	1465

Example 2. A similar set of data collected at Inland supports the data cited. On a furnace which was equipped with grizzlies that screened the coke going into the skips, a test was made by discontinuing screening for a period of two weeks, with all other factors as constant as possible. The grizzlies were set to screen out all fines less than 1 in. On October 16 the grizzlies were shut down for 7 hours, on the 17th for 12 hours and at 8:00 A.M. on the 18th discontinued entirely until November 1. No changes were made in furnace operation during the test run; wind, method of charging, size of tuyeres, filling mark, etc., were all kept constant. It was necessary to replace one manganiferous ore with another on October 16 but these ores are similar and the change was less than 10 per cent of the total burden. On the 25th one old range ore was replaced with another old range ore of similar physical and chemical characteristics and this change also was less than 10 per cent of the burden.

The grizzlies were shut down the first time at 12:01 A.M., October 16 and started at 12:01 A.M., November 1.

TABLE 3

The Effect of Discontinuing the Screening of Coke on Blast Furnace Practice

	Average, Sept.	Oct. 1–15	Oct. 16–31	Oct. 22–31, 10 days	Nov. 1–14, incl.
Average tonnage	831	822	789	778	812
Coke rate	1722	1731	1818	1834	1711
Number of off casts	0	0	7	5	1
Variation in silicon	.088	.097	...	.155	.185
Variation in sulphur	.0018	.002	.0026	.0026	.0025
Average blast temperature	1191	1183	1010	1062	1205
Average silicon	1.03	1.00	1.09	1.09	1.02

It is noticeable that the average tonnage fell from 822 during the period of October 1 to 15th, to 778 for the period from October 22 to October 31, a decrease of an average of 44 tons per day.

The minus 1¼ in. coke increased from 13.77 per cent to 20.46 per cent, that is, 6.69 per cent. It is interesting

that the coke consumption increased from 1732 to 1834, that is, 103 lb. per ton of iron, or 5.6 per cent. From this we conclude that the saving in coke consumption was equivalent to the fines screened out.

The average screen test of the coke for the three periods is shown in Table 4. The per cent through an 1¼ in. screen is higher from October 22 to 31st because the fines are included. This affects all the sizes.

TABLE 4

Size of Coke during Test Periods

1935	Number of 8-hr.	4 in.	3 in.	2 in.	1¼ in.	—1¼ in.	Average weight of sample
Sept. 1–30 (incl.)	30	.51	7.86	36.70	42.19	12.80	1137
Oct. 1–15 (incl.)	15	.41	7.48	34.43	43.91	13.77	1141
Oct. 22–31 (incl.)	23	.37	7.26	32.86	39.08	20.46	1166
Nov. 1–14 (incl.)	17	.91	10.70	35.12	41.00	12.32	1141

Irregularity in size of materials charged into the furnace contributes to irregularity of furnace operation. A convenient method of measuring furnace irregularity is to note the difference between succeeding casts of both silicon and sulphur and determine an average. For instance in the silicon, one cast may be 1.00 per cent and the next 1.09 per cent, with a difference of .09 per cent.

TABLE 5

Variation in Iron Analyses During Test Periods

	Sept., per cent	Oct. 1–15, incl., per cent	Oct. 22–31, incl., per cent	Nov. 1–14, incl., per cent
Variation, silicon	.088	.097	.155	.085
Variation, sulphur	.018	.002	.0026	.025

The variation of .097 per cent in silicon during the first period from October 1 to 15th, and the increase of 60 per cent to .155 per cent is significant as is also the increase in sulphur variation from .002 to .0026 per cent, or 30 per cent. It has been generally found that installation of coke sizing equipment has improved the uniformity in analysis of the iron produced.

INFLUENCE OF FINES IN COKE ON FURNACE OPERATION

Fines in blast furnace coke are detrimental for two reasons. They decrease the voids in the furnace stock column which are effective for gas flow, and higher gas velocities are created. This condition promotes slipping, blowing through, hanging, and the result is high flue dust production and irregular furnace operation. Second, they are detrimental in that they contribute to non-uniformity in gas flow, which causes poorer radial distribution of the gas. If all materials charged into a furnace were of sufficient and uniform size, the gas flow would be uniform across any plane in the upper part of the furnace. The greater the disparity in size of the particles charged, the more non-uniform will be the radial distribution. If there were no fines, the range in size of coke would be from the minimum screen size up to about 4 in., but as soon as there is breakage, the range is from approximately 0 to 4 in.

DESIGN OF COKE HANDLING EQUIPMENT

Bearing in mind that coke breaks readily and that the resulting fines are detrimental to furnace operation, we made a particular effort in the design of this furnace to insure that the coke reached the stock column in the best possible condition. This meant that the amount of drop to which the coke was subjected must be reduced to a minimum and, second, that the coke be screened thoroughly just before charging into the skips.

Figure 1 gives the general arrangement around the skip pit showing the coke handling system. Only one-half of the installation is shown, as the coke bins are symmetrical about the center line of the skip. In normal operation the coke is dumped into the two outside bins and fed over the 42 in. feeder conveyor to a 4 ft. x 8 ft. vibrating screen. Each individual bin has a capacity of 67 tons or a total of 134 tons. Generally very large coke bins are built to provide a supply of coke in event of failure in transportation. However, they have the disadvantage that they promote breakage and segregation of coke. At this plant, coke is available to the highline either by belt or by railroad car and it was not felt that the possiblity of failure of the delivery of coke was likely enough to outweigh the disadvantage of subjecting all coke to the additional breakage in large bins. Smaller coke bins left room for ore bins to be built in back of them, and thus the overall length of the stock house was decreased. Another advantage of the smaller bin was that it required less head room, and so the discharge of the bin could be well above the stock house floor level. And by inclining the feeder conveyor, it was possible to collect the screenings on a belt and convey them out of the stock house to a main belt collecting coke screenings from the other four furnaces, which was at grade as shown in Figure 1, section BBBB. As all equipment is in the open and well above the stock house floor level, the arrangement can be readily inspected and maintained.

After screening over the vibrating screen, the coke falls and slides to a balance bin. This is built on the order of a wharf and holds about one and one-half skips of coke. The purpose of the bin is to make screening of coke independent of the filling of the skip. Screening coke directly into skips results either in delay or in inferior screening. The screening of the coke is controlled by an automatic cut-off located in the balance bin.

Between the two outside bins are two auxiliary bins with emergency chutes leading directly into the bal-

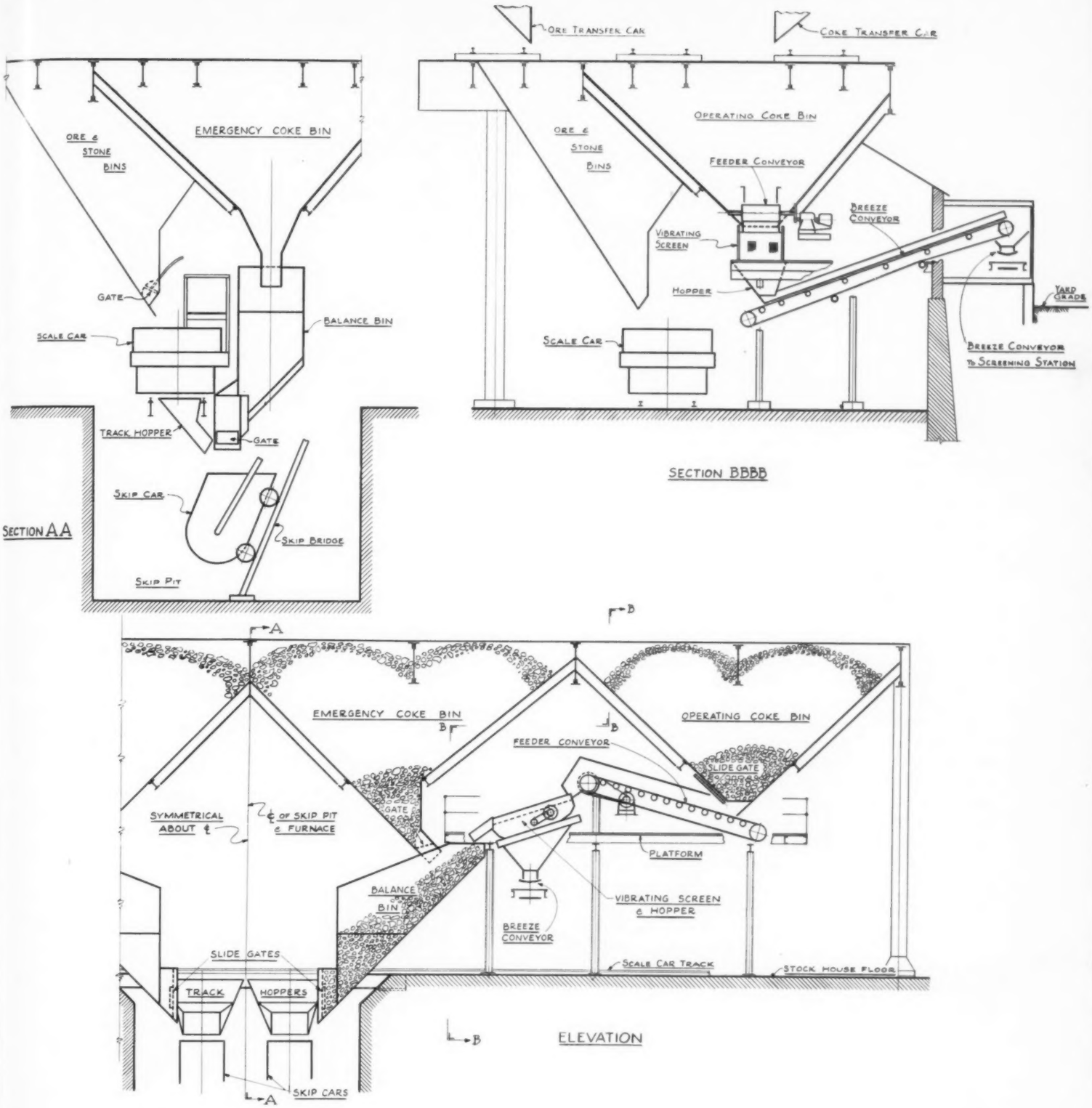


FIGURE 1—General arrangement of part of stockhouse of No. 5 blast furnace, showing the coke handling system which was designed with special consideration toward the maintenance of a uniformly sized coke.

ance bins. This permits shutting down either screening operation independently and without delay to the filling of the furnace.

The coke is fed into the skips through a side discharge chute. Directly after any coke has fallen into the skip, coke falls on coke, so that the breakage is the minimum. Attention was paid to the design of the skip car in order to minimize breakage. The necessary volume of the skip car was attained with minimum drop by making the horizontal dimensions the maximum. This maximum was limited, because too stubby a skip with bail type construction is liable to hang up on the furnace top in the dumping position.

The coke bin and skip layout has operated satisfactorily and economically. The maintenance cost is low, as is the cost of disposing of the screenings. This is most important, as the margin of profit in screening coke for the blast furnace is not excessive, and an inferior design may result in such high costs that much of the profit disappears.

The interior of the bin is lined with hard burned brick. This was laid up with generous curvature in the corners in order not to retard the flow of coke. The bins have been found to feed uniformly, that is, the entire area settles, leaving no hole up through the bin directly over the opening. We believe this is of moment. The detrimental effect of segregation in blast furnace coke bins is well known. It generally is avoided by keeping the bin full of coke. However, if the coke moves as a mass, there will be no segregation, and all skip loads will be the same.

The amount of drop to which the coke is subjected on the furnace top influences the size of the coke in the furnace. It varies a great deal according to the design but generally the vertical distance from the discharge point of the skip to the bottom of the large bell is from 20 ft. to 34 ft., in a series of drops from the skip to the inclined surface of the receiving hopper, to the small bell, and then onto the large bell. This is an important dimension because every piece of coke charged into the furnace is subjected to this drop and because any unnecessary height increases the amount of breakage.

The long drop was introduced with the aim of improving the distribution of the individual skip loads of material on the small bell. The small bell is loaded unsymmetrically each time because the skips discharge on either side of the center line. The resulting segregation of coarse and fine materials can be counteracted by decreasing the diameter of the small bell hopper and increasing its height. This of course adds to the total drop. The question then arises as to which is more important, improved distribution on the small bell or less breakage of coke.

There is considerable variation in the overall distance from the dumping point of the skip to the bottom of the large bell on our furnaces. This overall drop on No. 2 furnace is only 24 ft. while on No. 4 furnace it is 32 ft. On the latter the distribution on the small bell is much more satisfactory than on the former, yet the operation is not superior. If the shorter top were a disadvantage, it would be apparent in one of two ways: (1) more variation in the analysis of the iron from cast to cast and (2) shorter lining life. The fact that there was no greater variation in iron analysis is apparent when the percentage of quality iron produced per month is considered.

TABLE 6

Comparison of Percentage of Quality Iron

	No. 2	*No. 4*
Aug. 1936	99.6	96.6
Sept. 1936	96.9	97.8
Oct. 1936	97.8	95.7
Aug. 1937	97.9	96.1
Sept. 1937	96.3	93.4
Oct. 1937	97.0	94.4

The lining life on No. 2 furnace has been superior to that of No. 4 furnace. It should not be inferred that the excessive drop on top is the cause of shorter lining life. However, it can be concluded that the shorter drop on top has not had a noticeably detrimental effect on the length of campaign on No. 2 furnace. It produced 1,135,000 tons on the last campaign of basic and various grades of merchant iron and at the time of blowing out had no hot spots. It has produced 1,200,000 tons on this campaign of continuous operation, although it has been banked three times, had three campaigns of slow wind and two of high silicon merchant iron, and there is no evidence of impending failure at this time. These are not extremely high tonnages for a lining, even for a furnace only 19 ft. in hearth diameter, but it is certainly safe to conclude that there is no decided defect in the design.

We are inclined to feel that the importance of the distribution on the small bell has been exaggerated, as ample provision is made to take care of distribution by the rotating top. The function of the rotating top is to distribute these individual skip loads according to some predetermined sequence which results in a spiral in the furnace. A study of the gas flow at the periphery of three furnaces has proved that the rotating top does this job adequately. Naturally when the top fails to rotate due to mechanical or electrical failure, the furnace with the shorter drop has much poorer distribution of the stock than one with the higher drop. However, with the improved designs available the proportion of time that the top is not operating is so small that there is no need to design the furnace to allow for such possible failures.

FACTORS IN THE RADIAL DISTRIBUTION OF THE GASES

Furnace managers are experienced in varying operation according to the materials provided, in order to achieve the best possible radial distribution. However, exclusive of the reports of the Bureau of Mines, little has been published on this subject. When designing a furnace, we do not attempt to attain some known radial distribution, we attempt to duplicate the performance of certain efficient furnaces. Actually the reverse should be true, we should strive for the best radial distribution and efficiency would result. This is not done because we do not know enough about radial distribution; we are not sure which radial distribution is best for a given set of materials. This lack of knowledge was pointed out by Feldman and Stoecker[2] in a report on a series

of surveys on blast furnaces in which they were correlating radial distribution and furnace operation, indicating that the most uniform gas flow occurred with double charges. However, the efficiency of the furnace, in behavior and coke consumption, was poorer than with less uniform gas flow. Since we cannot know how uniform a gas flow is required for the ideal radial distribution, it seems illogical to discuss what factors in design should be chosen to attain it.

Because we do not know what radial distribution is desired, we can only judge the desirability of a certain distribution from the efficiency of the furnace at the time. The radial surveys that have been taken on No. 5 furnace will be presented. We will then present the most important factors in the design, operation and materials used which resulted in the radial distribution shown in these surveys. And last, operating data will be presented for the periods during which the surveys were made. From these we can judge the efficiency of the furnace, and then draw conclusions as to the desirability of the measured radial distribution.

GAS SURVEYS ON NO. 5 FURNACE

The surveys were all made along one radius at a plane 6 ft. 6 in. below the stock line. The plane was 13 ft. 6 in. below the closed big bell and 21 ft. 0 in. below the deck ring. The sampling tube was identical with the one used and described by Kinney[3] and all samples were collected over mercury. We have found on this furnace that the surveys are more representative if the samples are taken as the tube is being withdrawn rather than as it is inserted. The latter method tends to be inaccurate, particularly on furnaces of larger stock line diameters or on furnaces that are traveling very fast, because the movement of the stock carries the pipe downward. Consequently the end of the pipe may not reach the center of the furnace. The procedure of taking samples as the tube is being withdrawn is also inaccurate, in that the tube is interfering with the normal flow of gas, but it is believed to be a less serious inaccuracy.

When a survey was to be made, the tube was pushed or driven directly into the center of the furnace; generally this could be done very readily. After the gas had been blowing freely for about 10 seconds, a sample was collected, the tube withdrawn 6 in., and another taken. This process was continued until the 21 samples had been taken, a procedure which generally took from 12 to 22 minutes. Naturally, the end of the tube was moving downward with the stock, but withdrawing the tube was always tending at the same time to correct for this vertical displacement.

In Table 7 are tabulated the results of all surveys taken in May and June. In order to expedite analysis of the gas, only carbon monoxide and carbon dioxide determinations were made. From the tabulated data,

TABLE 7

No. 5 Furnace Gas Surveys

Date	Per cent CO_2																				
	W	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
5- 2-39	8.8	15.0	17.2	18.4	19.1	19.4	19.6	19.8	19.7	19.5	19.1	19.3	18.8	18.7	18.9	18.8	18.3	...	16.5	15.8	13.6
4	15.0	13.1	14.8	16.1	17.0	18.3	18.2	17.3	17.6	19.2	19.5	19.4	19.2	19.3	19.5	19.3	18.6	17.9	16.0	12.3	11.9
5	7.8	6.9	13.2	14.7	17.1	17.0	17.3	17.6	18.3	18.4	18.7	19.2	19.1	19.3	17.6	15.8	14.6	14.2	13.1	10.2	9.4
9	12.0	11.3	11.9	14.1	17.4	18.1	16.8	18.1	18.0	18.3	18.4	18.2	16.1	15.1	15.0	13.6	13.3	11.3	10.3	9.1	12.0
23	8.9	13.3	15.8	17.0	17.1	18.0	17.9	17.8	18.2	18.3	18.2	18.1	19.4	17.4	17.3	17.0	16.8	15.4	12.4	11.7	11.6
6- 5-39	12.7	12.8	12.3	13.1	15.9	17.1	17.4	17.9	17.9	17.9	18.1	18.2	18.3	18.3	17.9	17.0	16.4	16.5	11.0	9.9	9.9
6	10.0	12.3	13.3	14.4	16.6	17.8	18.3	18.7	18.5	18.8	18.7	18.6	18.0	17.7	16.7	16.0	14.4	12.5	10.8	9.0	9.9
7	11.0	13.7	16.3	19.0	19.0	19.2	19.1	19.0	19.0	19.1	19.0	18.3	17.5	15.8	16.0	15.2	13.1	...	11.4	12.0	8.7
8	9.0	11.1	13.0	15.5	16.6	18.5	18.5	18.4	18.4	18.4	18.6	18.2	...	17.4	17.4	16.8	15.3	13.3	11.8	10.0	9.2
9	10.2	10.9	14.0	19.1	19.3	19.7	19.0	19.3	19.3	18.6	18.2	18.1	16.6	14.6	13.3	12.1	10.3	5.1	3.7	2.9	4.6
19	5.7	9.6	10.0	15.3	17.3	17.9	18.7	19.4	20.0	20.3	19.7	19.4	19.2	17.7	17.7	16.7	13.3	11.1	8.0	6.9	7.6
19	4.5	6.6	8.7	10.5	16.2	15.9	16.6	17.5	18.4	19.2	19.5	19.8	18.3	18.6	16.6	14.8	...	14.0	10.5	9.5	11.7
Average	9.6	11.4	13.4	15.6	17.4	18.1	18.1	18.4	18.6	18.8	18.8	18.7	18.2	17.5	17.0	16.1	14.9	13.1	11.3	9.9	10.0

	Per cent CO																				
5- 4-39	28.2	28.8	27.2	25.3	24.2	21.6	21.6	21.8	21.3	20.1	19.6	20.0	20.0	20.1	19.2	19.8	19.6	19.7	21.0	25.4	26.0
5	31.0	...	25.4	25.8	22.3	22.5	22.4	22.1	22.2	22.1	21.3	20.3	20.7	21.7	22.9	25.9	27.8	28.6	30.5	34.4	34.6
9	26.0	25.9	26.1	23.8	21.7	21.1	19.8	20.2	20.6	20.5	20.6	20.3	23.5	24.9	25.4	27.4	27.9	29.1	31.3	31.9	31.4
23	27.3	23.7	21.2	21.0	20.0	19.4	19.3	19.4	18.9	18.7	19.0	19.1	19.0	19.6	19.3	20.2	20.8	22.6	26.6	28.3	28.4
6- 5-39	30.6	30.0	30.5	28.9	24.7	22.8	22.4	21.7	21.6	22.3	21.7	21.7	21.6	21.5	22.1	22.7	23.1	23.5	28.6	29.7	29.7
6	28.9	26.9	25.9	24.6	23.2	22.1	21.9	22.3	22.0	21.5	21.3	21.6	21.8	22.1	23.1	24.0	25.8	27.9	30.0	32.3	31.1
17	30.0	26.5	23.5	21.8	21.8	21.8	21.7	21.8	20.6	20.7	21.8	22.7	24.1	27.8	26.6	27.8	30.7	...	32.6	32.0	34.7
18	31.2	28.1	26.0	24.0	23.4	22.6	22.7	22.6	22.3	22.6	22.7	23.2	...	24.7	25.3	25.3	27.6	29.6	31.7	33.5	33.7
19	30.8	27.6	26.2	21.1	20.9	21.3	21.2	21.3	21.3	21.8	22.2	22.3	23.8	25.8	27.7	28.9	30.9	36.9	38.3	38.5	37.4
19	35.9	30.6	28.8	24.6	22.8	22.3	21.3	20.8	20.0	19.6	20.2	20.6	20.6	22.3	22.3	23.6	27.7	29.7	33.7	35.7	34.8
19	36.2	33.6	31.3	29.0	23.3	24.1	23.6	22.9	22.0	20.5	20.5	20.3	19.7	21.4	23.4	25.2	...	26.5	30.9	32.3	27.7
Average	30.6	28.2	26.6	24.5	22.6	22.0	21.6	21.5	21.2	20.9	21.0	21.1	21.5	22.9	23.4	24.6	26.2	27.4	30.5	32.2	31.8

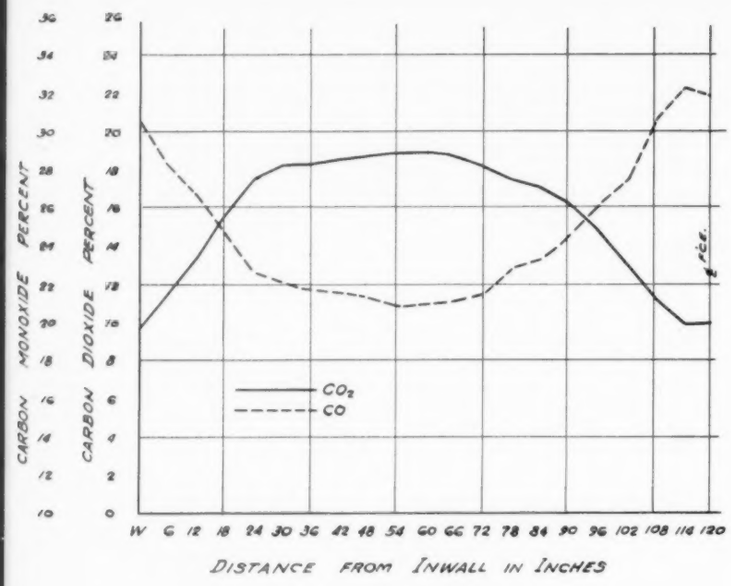

CARBON MONOXIDE PERCENT
CARBON DIOXIDE PERCENT
CO₂
CO
W 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 102 108 114 120
DISTANCE FROM INWALL IN INCHES

FIGURE 2—Curves showing the average carbon monoxide and carbon dioxide contents as determined by gas surveys on No. 5 furnace.

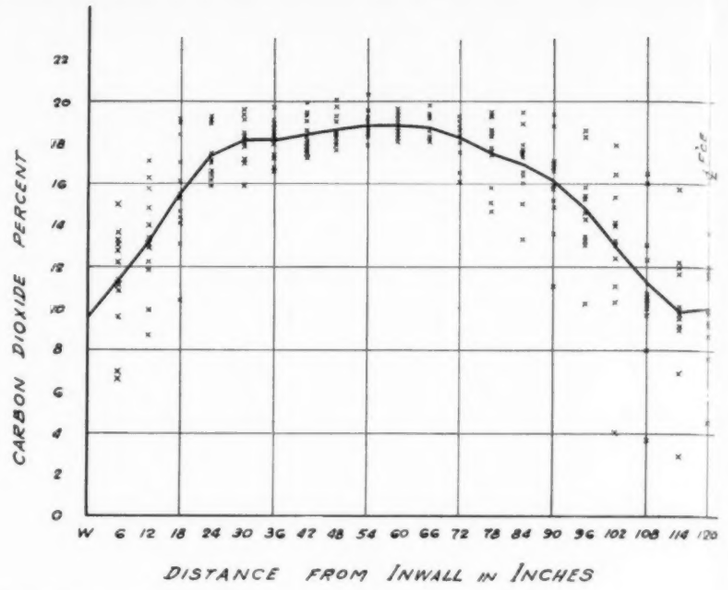


FIGURE 3—Graph showing average carbon dioxide content, together with the individual determinations made on No. 5 furnace.

individual surveys can be plotted if so desired. The average of all surveys is shown in Figure 2.

The individual surveys do not deviate a great deal from the average and the general character of all such curves is the same. The average survey shows that there are two zones in which the gas is deficient in CO_2—at the inwall and in the center. From the work done by Kinney, we can conclude that there is a higher gas velocity through these zones. It is probable that by changes in operation, the character of the CO_2 curve could be altered so there might be more gas flow either up the wall or up the center. It is not known that such changes would increase furnace efficiency. Figure 3 shows the average of the surveys together with the individual determinations. Although there appears to be wide dispersion of points, the individual surveys when plotted are all fairly smooth curves.

That the operation was normal is indicated by the operating data in Table 8 for the months of April, May and June, 1939.

TABLE 8

Operating Data—No. 5 Furnace

	Average daily tonnage	Lb. coke per ton of iron	Lb. dry flue dust per ton of iron	Per cent sinter in burden	Average Iron analysis		Average wind	Average coke ash, per cent
					Per cent sil.	Per cent sul.		
April	1,000	1,662	31.7	18	1.08	.025	57,800	5.37
May	1,007	1,665	27.0	18	1.04	.025	59,300	5.06
June	1,018	1,736	36.8	18	1.07	.026	60,000	5.94

The furnace operated smoothly during the entire period although there was some fluctuation in the efficiency. The sulphur in the iron was satisfactory; 8 per cent of the iron produced was over .030 per cent sulphur and none over .035 per cent. The filling, height of stock line, materials used, size of tuyeres, were constant during the period. No scrap was charged.

The surveys are of value merely as records of the actual condition of a furnace that is operating normally. If similar surveys are made on a furnace operating abnormally, a comparison of the two sets of surveys would show points of difference, which should indicate desirable changes.

The radial distribution which was measured on No. 5 furnace and which occurred with the efficiencies reported, is the result of a combination of factors, the most important of which is the bell clearance of 2 ft. 6 in. This dimension has been the subject of much discussion. Small variations have frequently been conducive to very good or very bad results. There has been a desire to establish some empirical formula to determine what is the correct ratio between the size of bell and the stock line. If such a formula were available, it would eliminate an uncertainty which causes considerable concern when designing a blast furnace.

Unfortunately no rule for bell clearance can be established which can simply be applied. There are many factors which determine the radial distribution of the gases, and bell clearance is significant only when considered in relation to the others. Some of the other influences are: the amount of straight section at the top of the inwall, the angle of the large bell, overhang of the large bell, speed of drop of large bell, inwall batter, the character of materials charged, method of filling the furnace, the amount of water charged, etc. We have

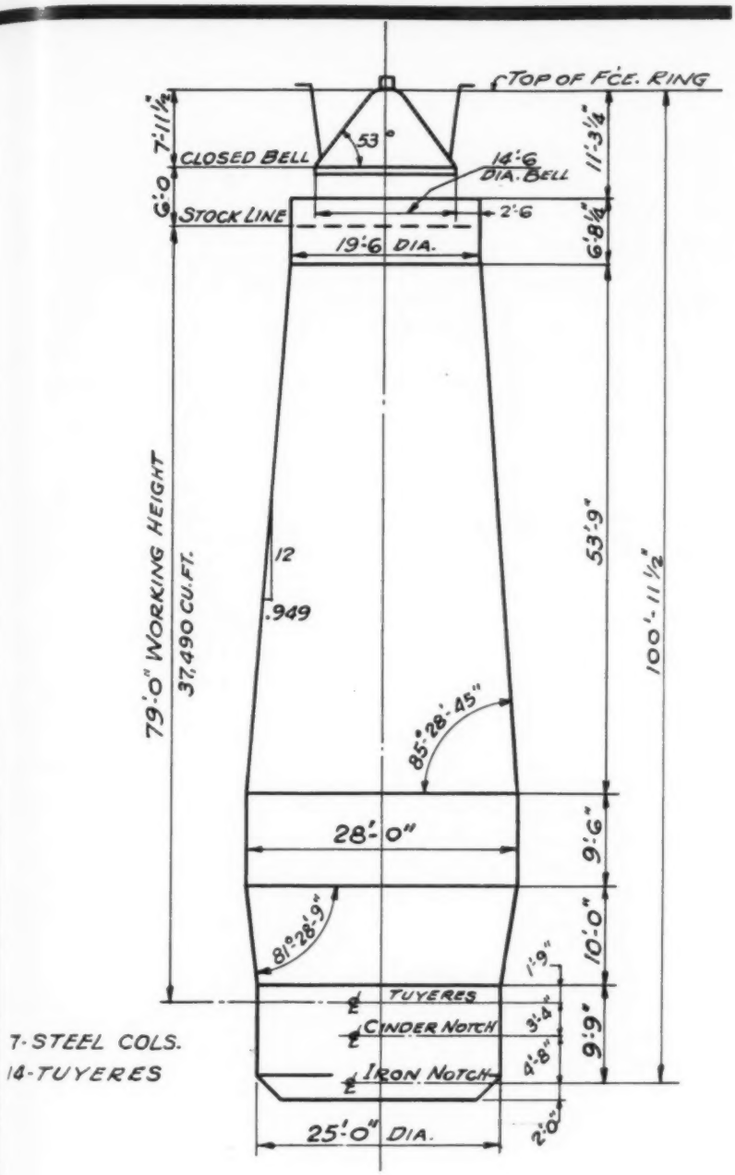


FIGURE 4—The design of No. 5 furnace received careful consideration from the standpoint of distribution of gas flow.

already discussed the factor of one material charged, namely, coke.

Figure 4 shows the lines of No. 5 furnace including most of the details of design which have an influence on the gas flow along the radius. In addition to the design there are certain factors in operation which have influence. The furnace is charged with a five skip fill—ore, ore, stone, coke, coke. The two skips of coke weigh about 10,000 lb. The furnace is filled to within 7 ft. of the closed bell. The large bell opens in 9 seconds. The wind blown, as shown in various tables, varied from 57,000 to 60,000 cu. ft. per minute.

The burden consisted of 82 per cent Lake Superior ores and 18 per cent sinter. No scrap or scale was used. All coke was screened over a 1½ in. screen as it was discharged into the skip.

TABLE 9
Operating Data for Two Periods on No. 5 Furnace

Date	Tonnage	Blast temp., deg. F.	Average wind	Delays	Si	S	Burden
May 2	1,057	1,180	57,000	....	1.02	.026	23,056
May 3	1,001	1,090	57,000	....	1.10	.025	22,900
May 4	984	1,030	57,000	....	1.21	.026	23,280
May 5	1,027	1,160	57,000	10 min.	.95	.031	23,066
May 6	968	1,075	57,000	....	1.10	.029	22,867
May 7	1,019	1,165	57,000	....	1.05	.027	23,006
May 8	1,007	1,075	57,000	....	1.10	.028	23,400
May 9	939	1,160	58,000	....	1.15	.027	22,908
Average	1,000	1,117	57,125	....	1.08	.027	23,060
June 5	1,041	1,150	60,000	....	1.12	.024	21,936
June 6	982	1,110	60,000	....	1.13	.024	22,282
June 7	1,051	1,210	60,000	....	1.09	.023	21,922
June 8	974	1,130	60,000	6 min.	1.06	.023	21,784
June 9	959	1,020	60,000	....	1.24	.024	21,900
Average	1,001	1,124	60,000	....	1.13	.024	21,965

SURVEYS AS AN INDICATION OF FURNACE EFFICIENCY

While many surveys such as reported may be of some value in the future as a guide in furnace design, the primary purpose of making them was to gain additional information in the hope of increasing furnace efficiency. The best radial distribution for any given furnace with given materials can be determined only by comparing surveys made during periods when the furnace was operating at different efficiencies. Thus we can learn which factors are correlated with each condition and are causing variations in the surveys, and in time we can learn which factors to try to vary to attain the desired condition of maximum efficiency.

In Figure 5 are shown the average of four surveys covering an 8-day period in May and an average of five surveys covering a 5-day period in June. The curves are similar in general character, but differ in a lower CO_2 content starting at 60 in. from the wall and extending into the center of the furnace. All factors within the control of the furnace operator were the same in these two periods. Table 9 gives the principal operating data for the periods. The lower efficiency is apparent in the lower burden carried. The iron bearing materials were the same. The average burden during the second period was 4.7 per cent less than the first, so although the wind had been increased 5.3 per cent, the average

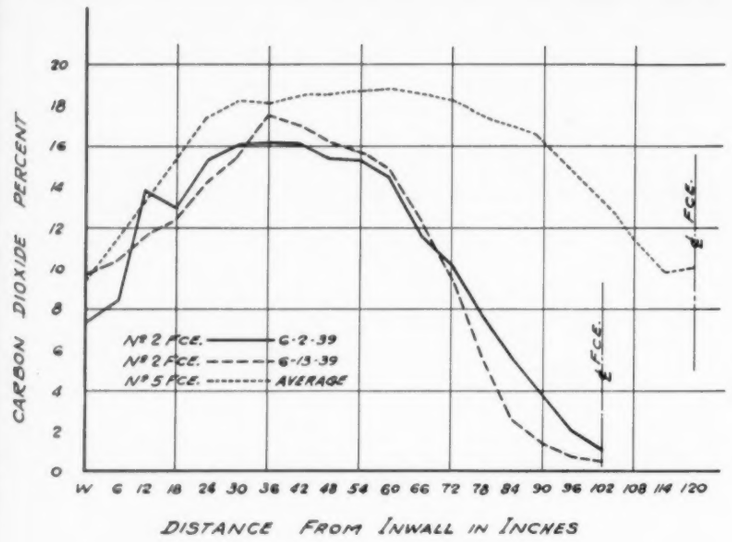


FIGURE 7—Curves showing comparison of results of gas surveys on No. 2 furnace with average from No. 5 furnace.

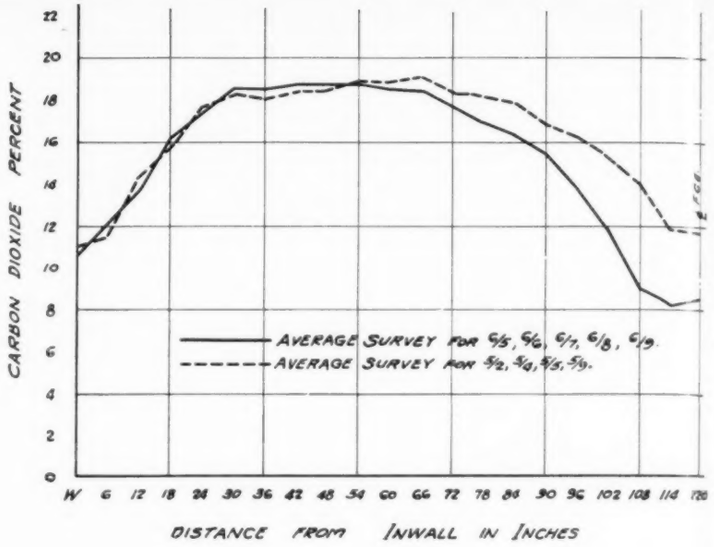


FIGURE 5—Averages of gas surveys show lower carbon dioxide contents during periods of lower furnace efficiency.

daily tonnage was the same. We can conclude that the period represented by the first surveys was the most desirable. What must be determined next is, first, what caused the change from the higher to the lower efficiency and, second, how the more desirable condition can be duplicated.

RELATIONSHIP BETWEEN THE TEMPERATURES AT THE INWALL AND FURNACE SURVEYS

If surveys are to be used as a guide to furnace operation, it will be necessary to make them frequently. Since this is difficult and costly, it would be an asset if a more convenient method of collecting this data were available. The use of thermocouples in providing data for studying the flow of gases at the wall was presented in a paper by the author on "The Peripheral Distribution of Gases in the Blast Furnace."[4] In that paper it was pointed out that the data from the thermocouples in the inwall was helpful in that they "served as a crude measure of the radial distribution of the gases and showed in what direction changes should be made." The surveys which have been presented were a continuation of the study of gas flow in the stock column and were conducted in an effort to determine to what extent the inwall couples do indicate the radial distribution. The following data show that they are inadequate to measure the small variations in gas flow which however are sufficient to be of moment in furnace operation.

In Figure 6 are plotted two surveys taken on May 2, 1939, and on May 23, 1939. The general character of the CO_2 curves is similar—although the average CO_2 content of one survey is less than that of the other. Below the surveys is shown the total burden on the furnace (iron bearing materials identical) for the two days before the survey was taken, together with the burden for that day. The increases and decreases in burden are those made by the furnace foreman in his usual routine of anticipating changes in furnace temperature. The burden of the second period is about 4 per cent less than that of the first and the lower burden checks with the lower CO_2 content of the survey.

Below the burden is reproduced the inwall temperature record for a 7-hour period during which the survey was made. The four couples are located in a plane 21 ft. 6 in. below the deck ring and 6 in. below the plane of survey. The average inwall temperature of the four couples was 1205 degrees F. at the time the first survey was taken and 1230 degrees F. for the second. This is not a great enough difference to suggest the variation that exists, and it can be concluded that the temperatures at the inwall are only a crude measure of radial distribution of the gases, not an accurate one.

The practice on the furnace for the two three-day periods is shown in Table 10. The lower burden is reflected in the lower tonnage produced if the difference in the wind blown is taken into consideration. The wind had been increased 5.3 per cent but the tonnage had increased only 1.5 per cent.

The surveys made on No. 5 furnace are more interesting when compared to similar ones made on No. 2 furnace during the same period. The data for two typical surveys are shown in Table 11 and these are plotted in Figure 7. These surveys indicate that there is relatively more gas flow up the center than there was on No. 5 furnace although the flow of gas at the wall is about the same. The fact that this furnace was operating less efficiently than No. 5 furnace is evident when

TABLE 10

Practice During Two Three-Day Periods

	Tons	Top temperature	Wind	Charges	Blast temperature	Silicon	Sulphur
April 30	1,001	345	57,000	176	1,125	.98	.024
May 1	970	340	57,000	182	1,100	1.17	.024
May 2	1,057	315	57,000	185	1,180	1.02	.026
Average	1,009	333	57,000	181	1,135	1.06	.025
May 21	1,066	335	60,000	187	1,165	1.13	.025
May 22	953	310	60,000	186	1,160	1.12	.023
May 23	1,055	325	60,000	191	1,130	.89	.026
Average	1,025	323	60,000	188	1,152	1.05	.025

the CO_2 curves for both furnaces are compared as was done in Figure 7. The fundamental question immediately arises as to why the CO_2 averages are higher on No. 5 furnace. There is not enough data available to answer this definitely but it is believed the fact that No. 2 furnace is 88 ft. 3 in. high, where No. 5 is 100 ft. 11½ in., is the most important factor. Another difference was probably in the iron bearing materials charged as no sinter was being used on No. 2 furnace while 18 per cent was being used on No. 5 furnace. The remainder of the ore burden was essentially the same. The same coke was being charged as on No. 5 furnace and the screening facilities were the same.

The gas surveys on No. 2 and No. 5 furnace which have been presented are of interest. They will be useful only after enough data has been collected under different conditions to isolate the various factors which influence them.

HEIGHT OF FURNACE

The proper height of a blast furnace is still a matter of discussion although the recent trend has been definitely towards greater height. Barrett[5] discussed this problem and recommended that the modern furnace should not be less than 100 ft. Further discussion would hardly be necessary were it not that this decision is sometimes questioned when lack of consideration of the whole leads to other conclusions.

The question of the proper height of a furnace should be approached from both the empirical and theoretical angles. From the empirical aspect, in general, the greater the height of the furnace, the greater the amount of hanging and slipping, other things being equal. The irregular movement of the stock is very damaging, so what is gained by added height is frequently lost by the greater furnace irregularity. But as the diameter of the furnace is increased, there is less friction on the walls per unit of volume, less chance of arching, and it is possible to build the larger furnaces higher without experiencing any more irregularity.

The correct theoretical approach is important because it directs our thinking which later is translated into action. The blast furnace operates on the counter current principle and will have attained its highest efficiency when the present waste products have been used to the ultimate. When this ultimate is achieved, the top gases will issue from the furnace at about the same temperature as the incoming materials, and the reducing power of the gas will have been spent. The average top gas of 15 per cent CO_2 and 26 per cent CO is still strongly reducing to Fe_2O_3 and some of this reducing power could

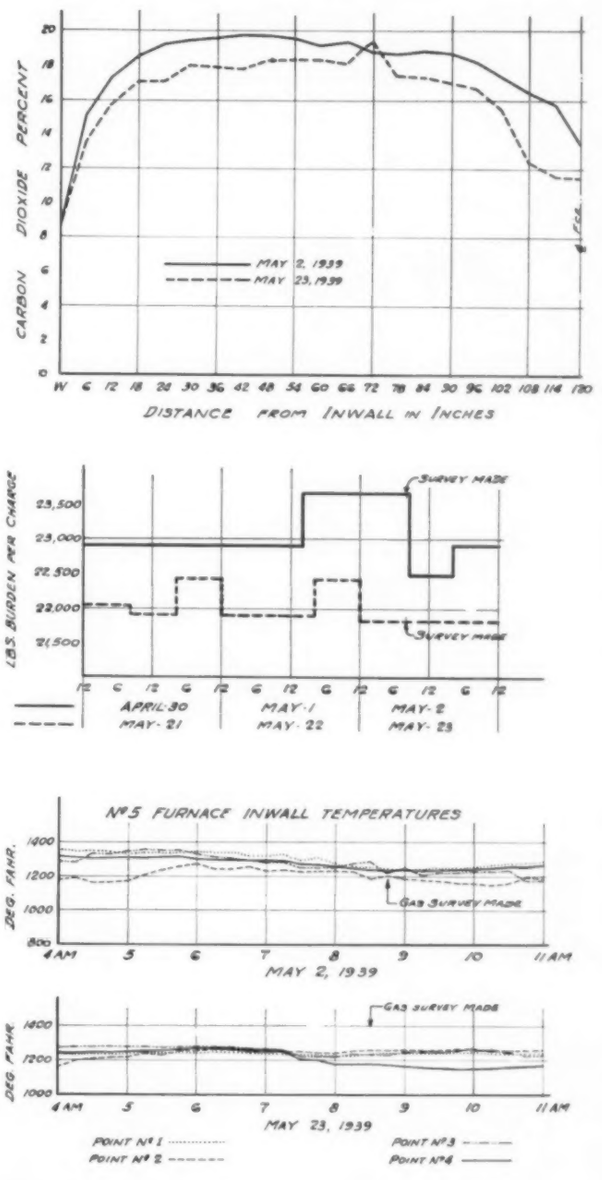
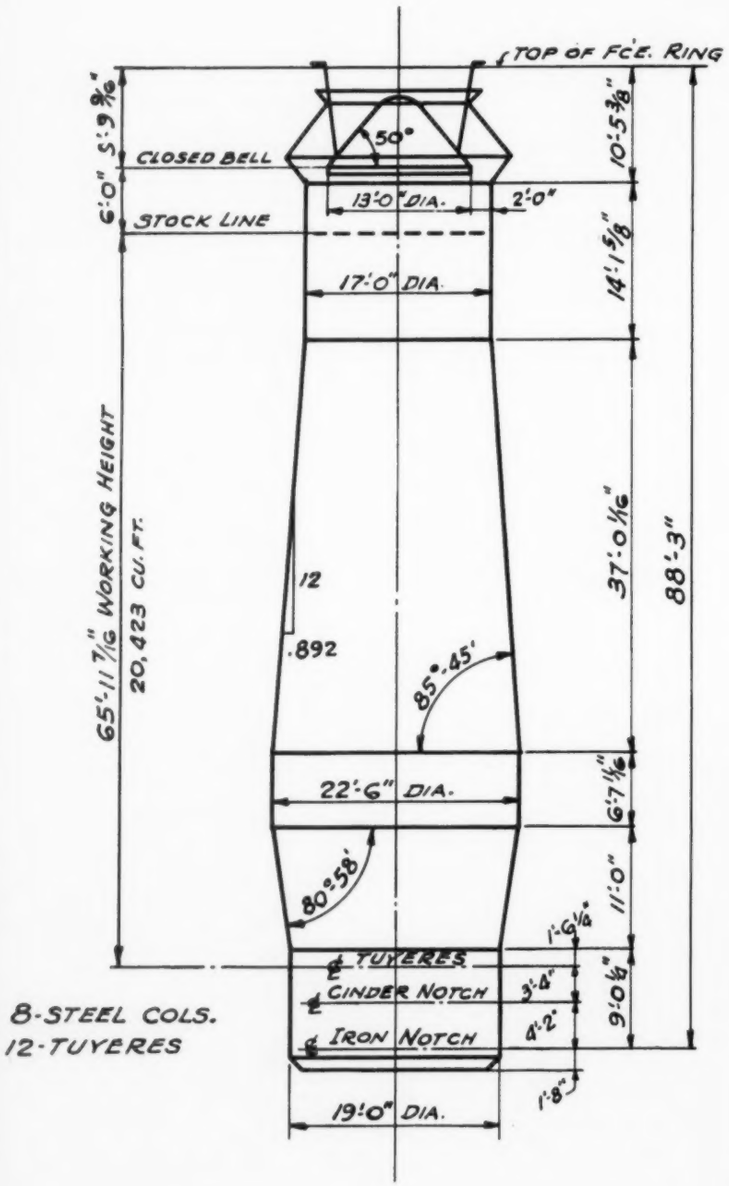


FIGURE 6—Graphical presentation of results of two surveys taken on No. 5 furnace, showing burdens and inwall temperatures.

be used. We do not know how much, but we have taken gas samples in furnace surveys which show in one case 20.0 per cent CO_2 and 18.4 per cent CO and in another, 19.8 per cent CO_2 and 18.8 per cent CO. Now, Matsubara's study[6] shows that gas is still reducing to Fe_2O_3 if it contains as much as 85 per cent CO_2 and 15 per cent CO. Avery[7] has proposed that this added efficiency can be attained by operating the blast furnace under pressure. The pros and cons of this suggestion will not be discussed here. What is important is for us

FIGURE 8—The lines of No. 2 furnace offer no explanation of its lower CO_2 average other than its smaller height.



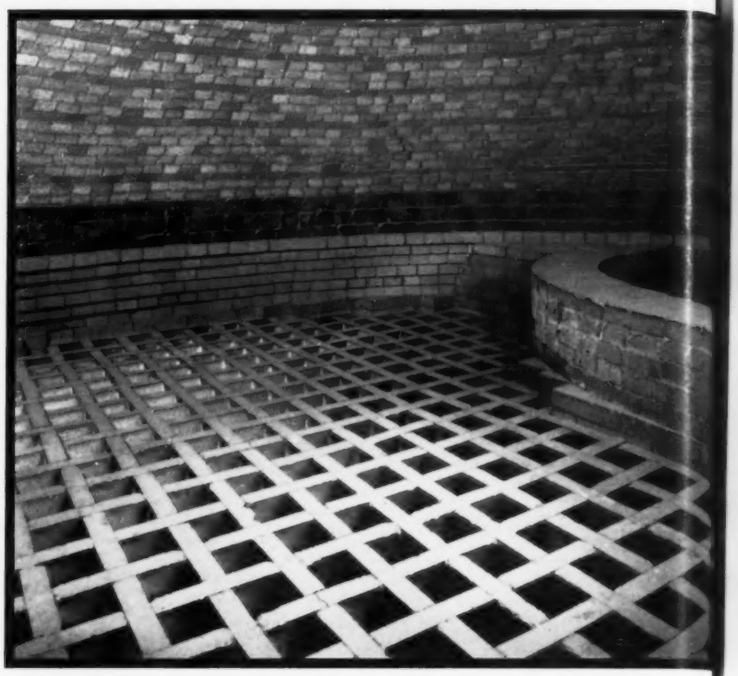


FIGURE 9—Stoves of basket weave construction, with 2½ in. thick brick and 5¼ in. openings, have operated 31 months without damage.

to realize that here is a promising question for study.

Improvement in overall efficiency can be effected in many ways, such as: better sizing of raw materials, improved reducibility of materials charged, and a longer period of contact between gases and ore. The latter can be effected either by slower progress through the furnace or by still further increases in furnace height. And after such improvements have been made, we may reach the

FIGURE 10—This tile, with 2¼ in. thickness, is from the top of a stove which had been in operation 80 months.

TABLE 11

No. 2 Furnace Gas Surveys

Date	Per cent CO_2																	
	W	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102
6- 2-39	7.4	8.6	13.8	13.0	15.3	16.0	16.1	16.1	15.3	15.3	14.6	11.7	10.1	7.9	5.8	3.9	2.0	1.0
6-13-39	9.8	10.3	11.7	12.3	14.2	15.4	17.4	17.0	16.2	15.8	14.9	12.4	9.8	5.7	3.6	1.3	.7	.5
	Per cent CO																	
6- 2-39	31.6	30.4	25.4	26.2	24.5	24.0	23.9	24.1	24.7	24.7	25.4	28.3	30.5	33.1	35.6	37.7	39.0	41.4
6-13-39	30.8	29.7	28.3	27.7	24.6	24.4	22.2	22.6	22.8	23.4	24.1	26.8	29.4	34.3	37.2	39.7	40.3	40.7

stage when it will be economical to dry our raw materials with cheap fuel, quench all the coke by a dry quench process, and perhaps, as proposed by Guthmann,[8] calcine the limestone in such a manner as not to destroy its physical properties before charging it into the blast furnace. But as long as water is charged into a blast furnace to decrease top temperature, heat is escaping instead of doing useful work and further consideration should be given to the problem of making use of this heat, and one way is to increase furnace height.

HEATING OF THE BLAST

Since the general adoption of fine cleaned gas for use in stoves, plugging of checker flues is no longer a problem, and it has been possible to depart from the conventional large flue openings. The maximum amount of heating surface can be secured by using the smallest possible opening and thinnest possible brick section. But with increased efficiency, we have enlarged the possibility of failure in the top zone, because as we decrease brick thickness, in general, we decrease strength. This problem is particularly important in the upper portions of the stove where the brick is subjected to the highest temperatures, and considerable discussion arises as to the minimum thickness of brick that can be used at this point and still retain sufficient strength.

Our experience has shown that stoves of standard basket weave construction with a 2½ in. brick thickness and a 5¼ in. checker opening withstand heat successfully with fillers in these flues up to 6 ft. from the top. Figure 9 is a photograph of a stove, of this design, which was built in February, 1936, and had been in actual service for 31 months. The checker work was in perfect condition and the stove was again closed up and ready for another campaign on the furnace. Figure 10 is a photograph of tile from the top of a stove built in July, 1931, which has been in operation 80 months. The layer next to the floor shows opposite ends of tiles from the top course, those above from the second and third courses. The thickness of the brick is 2¼ in., and it is evident that this has been sufficient to withstand the heating action in the highest temperature zone of these stoves. The stoves on No. 5 furnace were built of standard basket weave with a 2½ in. brick and 5¼ in. checker opening, and fillers in the flues to within 5 ft. 8 in. from the top.

All blast furnaces are equipped with a mixer arrangement so that cold air from the engine room can be mixed with the hot air from the stoves in definite proportions to attain the required temperature. It has been found that the degree of mixing that takes place varies a great deal and under extreme conditions there are temperature differentials as high as 500 degrees on opposite sides of the bustle pipe. This non-uniformity must be detrimental to furnace operation.

We have spent considerable time studying the distribution of gases around the peripheries of several of our furnaces and we have concluded that the more uniform this distribution the more satisfactory the furnace operation. We know that one of the factors which contributes to the non-uniformity is uneven wear on the lining. We cannot state what causes the uneven wear, but it is logical to conclude that any maldistribution of the temperature of the blast at the bustle pipe would have some effect.

Some maldistribution of blast temperature is evident in Figure 11 which is a record of the temperatures at four tuyeres on No. 1 furnace. Stoves No. 1, 4 and 5 were being used, No. 2 and 3 being obsolete. When No. 1 stove was on the furnace, that mixer was used which entered the hot blast main horizontally and at right angles just beyond the stove and towards the furnace. When No. 4 and 5 were on the furnace, the mixer which entered the end of the hot blast main was used. Iron constantan couples were inserted through the peep sights into No. 2, 5, 8 and 11 blow pipes and the temperatures recorded on a multiple recording potentiometer. A portion of the chart is reproduced, which shows that the mixing was not satisfactory, particularly when No. 1 stove was on the furnace. The variations in temperature at the individual tuyeres are as high as 60 degrees. The poorest distribution had been evident when the mixer at the end of the main was used with No. 1 stove. The second mixer provision, previously described, was installed.

In some mixing systems the air from the stove travels through the main at its maximum temperature, approxi-

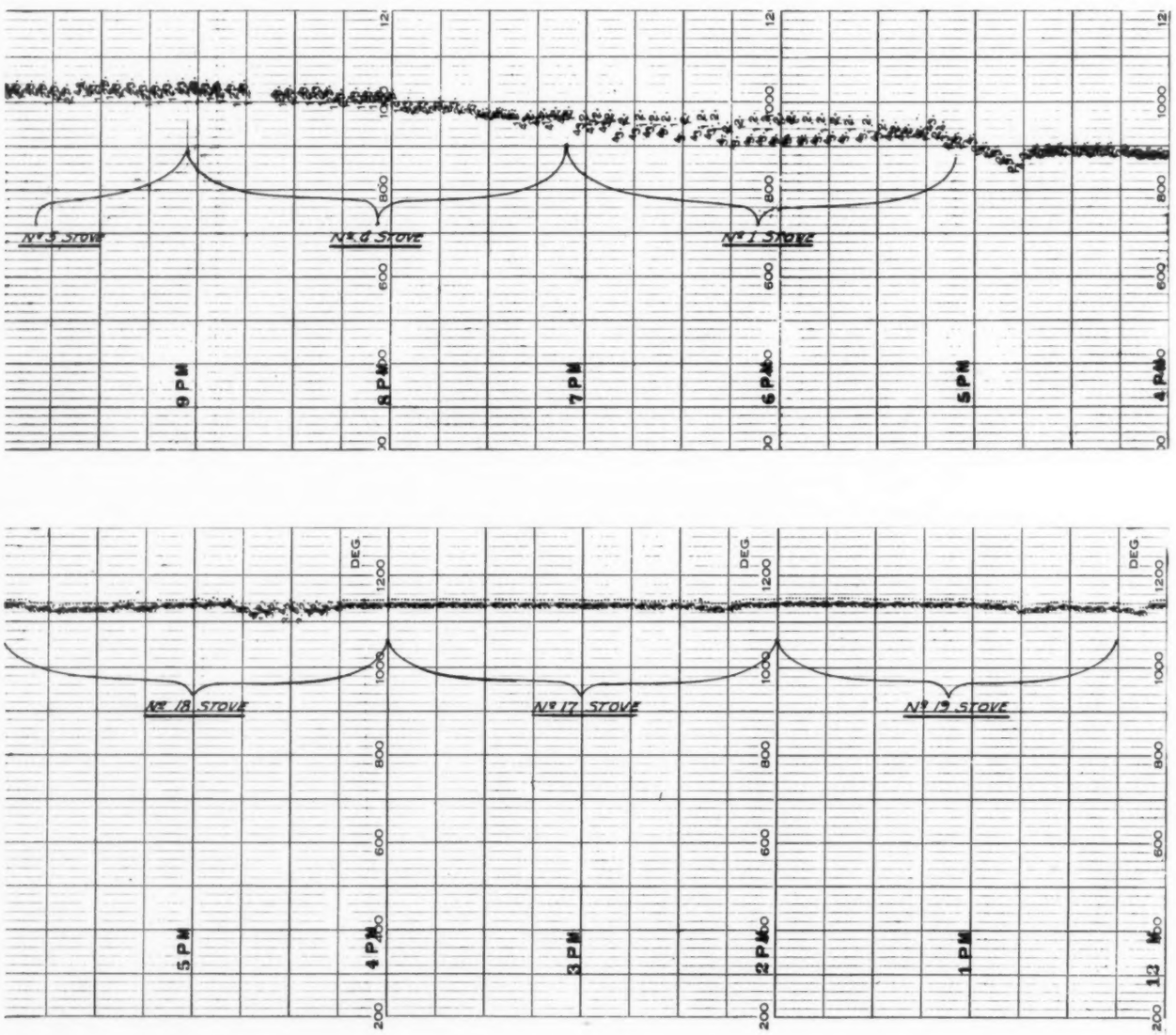
mately down to the furnace before the cold air is introduced. As the stove cools the temperature through the main gradually drops and the mixer valve is closed. The constant fluctuation in temperature makes it more difficult to maintain brickwork and main. In some types of mixing arrangements, the cold air is introduced at right angles to the hot blast main. This causes a spalling directly opposite the point of entrance, and necessitates occasional shut-downs of the furnace for repairs at this point.

We have achieved better mixing by introducing the cold air at the bottom of the hot blast valve drum on each individual stove, and such an arrangement was installed on No. 5 furnace. Figure 12 is a photograph of a portion of the record made when the blast temperature was constant during a 6-hour period when each of the three stoves was used on the furnace. The results are very satisfactory. The good results with the automatic temperature control are shown by the uniformity of the blast temperatures.

In addition to the better mixing of hot and cold air, this system has several other advantages. One of these advantages is the fact that the mixing occurs in the chamber of the mushroom type hot blast valve, so that there is a uniform temperature throughout the length of the hot blast main. The mixing occurs in the hot blast valve chamber on the stove side of the hot blast valve, so that if there should be any failure, repairs can be made without shutting down the furnace. No such failures have occurred on the other furnaces even though the system has been in use for about seven years.

FIGURE 11—Chart showing record of blowpipe temperatures at four tuyeres of No. 1 furnace, indicating improper mixing.

FIGURE 12—*(bottom)* Chart showing record of blowpipe temperatures on No. 5 furnace, with cold air introduced at bottom of each hot blast valve drum.



The amount of draft available in the stove stack is of interest not only because it influences the capacity of the stoves for burning gas but also because it assists in removing the gas from the bosh of the furnace when it is necessary to draft back. The draft available is largely a function of the temperature of the gases in the stack. With the improvement in the design of stove checkers, there has been a decrease in stack temperatures to as low as 250 or 150 degrees F., and consequently less stack draft. This has not been a serious problem in the burning of gas in the stoves because of pressure burners, but it has been a problem when "drafting back" on the furnace.

"Drafting back" consists of connecting the bottom of the furnace through the bustle pipe and one stove to the draft stack to draw away the bosh gases. If the draft is inadequate, there are two problems. It is difficult to work around the furnace when connections are broken. Second, the rich gases are not pulled away rapidly enough to prevent their mixing with air, and explosions result. We had experienced several such on another furnace, which fortunately did no damage.

A standard type of injector was installed in the stove stack on No. 5 furnace, to be used only when drafting back. It is provided with a 1 in. nozzle and consumes steam at a rate of approximately 6000 lb. of steam per hour. Table 12 shows the amount of draft available measured at the breeching at No. 18 stove, with and without the injector.

TABLE 12

Stove Draft with and without Steam Injector

No. 17 stove on gas	*No. 18 on furnace*	*No. 19 closed*
Draft without injector	.42– .50 in. H_2O	
Draft with injector	1.05–1.15 in. H_2O	
	No. 17	*No. 19*
Stack temperature, degrees F.	240	260

This has proved adequate and we do not believe any further provision is necessary for use in drafting back during furnace shut-downs.

CONCLUSION

Efficient blast furnace operation is the result of the correct combination of many details. No one detail in itself is of sufficient moment to spell failure or success, yet each is of sufficient importance to warrant careful consideration. In this paper we have presented some data and our views on four factors with the hope it will promote discussion and eventually aid in blast furnace development.

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DISCUSSION

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L. E. RIDDLE: First, I want to compliment Mr. Johnson on the gathering of data and presenting it as he does. There is no doubt but that we should hand our knowledge of furnace operation and design, and reasons for the latter, down to posterity, instead or doing as many of us have done, just handing it to our immediate associates. I think Mr. Johnson's manner of recording what he has found about this furnace is a fine thing.

I can only criticize the design and paper from what I saw on the screen. I knew nothing of the furnace until I saw it here. As you have asked me to say something, I suppose you want me to make some criticism of the design of the furnace. In that case, I will start at the bottom.

If I had that 25 ft. furnace in the Pittsburgh district, and had to use the kind of coke we use here (42 per cent remaining on a 2 in. screen, instead of 73.3 per cent as

shown by Mr. Johnson's tests of Inland coke) I would make my bosh steeper, between 83 and 84 degrees, instead of the 81½ degrees that I believe was shown. Of course, with that physically good coke, the steeper angle may not be needed. At the top I would increase the diameter to not less than 21 ft. instead of 19 ft. 6 in. as shown.

I noticed the length of the throat to be about 7 ft., which looked good. To get the stock line area as near 1 to 1 hearth area as possible, I would prefer a throat such as this one to long ones which usually are made to get higher batter in the inwall.

Building a new 25 ft. furnace, I would not make it short of 110 ft. in height. I feel sure that the larger hearth furnaces are going to come to that height. The trestle and stockhouse layout are fine and Mr. Johnson's reasons for making coke bins just chutes or funnels are right. Slopes in the ore bins look steep, as they should be.

I noticed that some of the figures showing practice stated only 1000 degrees average heat, and wondered why others used 1200 degrees. I wondered why, when you have ample stove capacity and the excellent 91 per cent fixed carbon, 87 per cent available carbon, physically strong, excellent sized coke, you do not use higher blast temperatures? I noticed the production averaged only about 1000 tons. If this is short tons, the furnace should make nearer 1200 tons a day with the materials they have.

One of the most interesting things I noticed was that they put the cold blast for temperature regulation in the bottom of their hot blast valves and obtained uniformity of temperature. We have always observed that the farther away you mix the hot and cold blast from the furnace, the more uniform the temperature of the air on both sides of the bustle pipe. The graph showed an exceedingly uniform temperature in all tuyeres, with the cold air being put in on each individual stove. This looked very good and seems to be an improvement.

On the whole, I would say that Mr. Johnson has designed a most excellent 1939 model furnace. I think that every operator would be glad to have one of the kind.

T. L. Joseph: It has been my privilege and good fortune to have the opportunity of discussing blast furnace problems from time to time with Mr. Johnson. The favorite topic of discussion has been gas distribution or some closely allied subject. This subject is not new but a number of plant studies conducted by Mr. Johnson have given it added significance.

Considering its size and capacity, the modern blast furnace is closely controlled with respect to the composition and the temperature of the iron produced. There are, however, periods when individual furnaces require much more attention to maintain the quality of the iron and some sacrifice of tonnage is unavoidable. Such periods of unsatisfactory operation may extend over weeks or in some cases months. The total economic loss may be large but up to the present the underlying causes and the cure have not been fully understood. Why, for example, should furnace capacity decrease 5 to 10 per cent with no apparent change in raw materials or operation.

In previous papers Mr. Johnson has shown that furnace efficiency is closely related to the distribution of the ascending gases through the charge. Moreover, his plant surveys on a number of furnaces have revealed irregularities in gas distribution which have explained the immediate cause for unsatisfactory furnace performance. Without the special effort he has made to follow the gas distribution on all of his furnaces, many periods of poor operation would have been shrouded in mystery.

Granting that many periods of irregular working can be attributed to improper distribution of the gases, the problem is far from ultimate solution. The causes for poor distribution must be determined and controlled. Mr. Johnson's paper is of particular interest because it examines coke quality, coke handling equipment and top design in relation to the most desirable distribution of the gas. The author presents data which show that an increase of 6.69 per cent in the amount of minus 1¼ in. coke decreased the average daily output 44 tons, increased the coke per ton by about 100 lb. and contributed to wider variations in iron analysis. Such data are, of course, a very good justification for coke handling equipment. Individual plants can estimate the savings due to better coke rates and larger output, but it is very difficult to estimate the value of a more uniform product which is likely the most important of all to the plant as a whole.

It has been suggested that operators should not hesitate about subjecting coke to mechanical shock before the fines are screened out at the blast furnace. The idea back of such a suggestion is that weak pieces of the coke will break down and be discarded before entering the furnace. If the coke is handled with great care before screening at the blast furnace these weak pieces do not break until the coke begins its travel through the furnace.

In the writer's opinion the handling of coke is more severe than the conditions inside the furnace in causing breakage. The need for strong coke to support the weight of the stock column has been over emphasized. Most of the time the charge is supported to a great extent by the buoyancy of the gas stream. Some abrasion no doubt occurs as all parts of the stock do not settle at the same rate. If the coke of the proper size is deposited at the stock line the operator will have done most of the job of providing a proper medium for maintaining the permeability of the charge. Some plants are fortunate in having at their disposal low ash and low sulphur coals which may not yield the strongest of coke. Certainly such plants are justified in handling their coke in such a manner as to minimize breakage.

The author states that the coke is passed over a 1⅛ in. screen at the coke ovens and then screened again at the blast furnace. I would like to raise the question as to whether two screenings are necessary or whether one thorough screening at the blast furnace would not be sufficient.

The variation in the total height of drop from the point of discharge from the skip to the bottom of the big bell closed is an interesting feature of top design. If it can be shown that the distributing top will take care of any irregularities in distribution on the little bell resulting from shorter drop of charges on top, then

there seems to be little justification for additional height of top. The author further states that a study of gas flow at the periphery of three furnaces has proven that the rotating top does the job of stock distribution adequately. Some further statement as to the character and frequency of surveys of peripheral gas distribution leading to this conclusion would be desirable.

The peripheral gas distribution is probably fairly uniform near the stock line most of the time. Mr. Johnson's work has shown, however, that it can be irregular at some distance below the stock line. The writer would like to ask whether the author has checked the peripheral distribution near the stock line, during periods when it is found to be irregular at distances of 10 to 15 ft. below the stock line.

The author takes the position that the shorter drop of stock in charging is preferable. One might infer that the new No. 5 furnace has a top which will require a comparatively short drop of coke. No statement is made, however, on this point.

The gas surveys showing the radial distribution of gas in No. 5 furnace are interesting particularly when compared with those for No. 2 furnace. It appears from Figure 7 that the radial gas distribution is more uniform on furnace No. 5. The CO_2 exceeds 16 per cent from about 18 to 90 in. from the wall, a band of 6 ft. Moreover, the CO_2 is about 9 per cent at the center of the furnace No. 5. The section of high CO_2 content is comparatively narrow for furnace No. 2. From 24 to 54 in. from the inwall, the CO_2 approaches 16 per cent. This distance or band of high CO_2 content is, however, only 2.5 ft. wide compared with 6 ft. on No. 5 furnace. The writer believes that the better coke rate on No. 5 furnace is partly due, at least, to more uniform radial distribution of the gas. The additional height of No. 5 furnace may be an important factor as the author suggests. The 18 per cent sinter in the burden on No. 5 furnace would favor a more uniform radial distribution of the gases.

A. L. Foell: I have had the great pleasure of collaborating with Mr. Johnson and his Inland associates during the past several years in the design of Inland's new No. 5 blast furnace and in the rebuilding of their No. 1 furnace. His paper sets forth in excellent manner the major considerations which entered into the design of No. 5 furnace and the highly satisfactory results which have been realized in operating this unit. The work that he has done in the preparation of this paper is very definitely a real contribution to the art of "blast furnacing" and points the way in the solution of some of the problems confronting both the engineer and operator.

I would like to bring to your attention a few of the other unusual features of this furnace which I believe are worthy of mention. The hearth is 25 ft. in diameter. There are 14 tuyeres and 7 rolled steel H-beam columns. The large bell is electrically operated by a positive opening bell operator designed to give straight line motion to the bell rod which is provided with protective means to prevent bending of the bell rod in case of accidental over filling of the furnace. The large bell is rigidly connected to the 7 in. bell rod by means of a stiffening cone.

The furnace top is provided with 4 equally spaced offtakes which are oval in cross-section approximately 8 ft. wide x 6 ft. high. From these, pairs of uptakes join into single pipes which meet over the center-line of the furnace. From this point a single downcomer is taken into the top of the dustcatcher. In this construction the length of travel of the gas passing through each offtake is exactly the same, thus assuring uniform gas distribution in the furnace stack.

The bustle pipe is anchored into the cast house structure to definitely maintain it in proper center against expansion of the hot blast main. The furnace shell is provided with platforms positioned 26 ft. below the top platform to give convenient access to the openings provided into the furnace for studying stock distribution, gas flow and inwall temperatures.

The furnace skips are operated at from 300 to 600 ft. per min. through a Ward-Leonard controlled skip hoist. Two mill type motors drive the skip hoist for which current is furnished by two d-c. generators of a motor-generator set. The hoist house is ventilated by filtered air under a positive pressure with separate ventilation for the hoist motors.

The stove operating platform is elevated and is at the same level as the cast house floor. The hot blast main is straight from end to end and joins the bustle pipe radially. The stoves and burners are each of sufficient capacity to operate the furnace on two stoves with full wind at normal hot blast temperatures.

The stock house bins are hand operated for which facilities were developed on certain bins for the easy withdrawal of sticky ores without hand poking. The cast house is arranged to accommodate four 100 ton iron ladles under the elevated floor and four 400 cu. ft. slag ladles on each side of the cast house.

In reference to Mr. Johnson's remarks on the thickness of walls of the checker brick I would like to point out that the 2½ in. thickness he has adopted is not necessarily the minimum which can successfully be used in the checker construction. Our experience has been that stoves lined with nested tile having 1¼ in. thick walls installed approximately 6 years ago are giving satisfactory service and from present indications will continue to do so far a good many years more.

Where disintegration of checkers in stoves fired with fine cleaned gas has been experienced this has been almost entirely confined to the top 8 to 12 ft. To line an entire stove with 2½ in. of brick in order to obtain longer life in the top portion of the checkers is less economical than to occasionally make replacements in this region if thinner wall checkers are used. I believe that the ultimate solution here is a matter of quality of refractories and not thickness of brick.

In conclusion I might make the suggestion that further contribution in the art of furnace design and operation could be made if other operators, whose furnace tops are somewhat different from those at Inland, would make similar tests on radial distribution of gas. The data thus obtained when compared with Mr. Johnson's data would enable both the operator and the engineer to study and evaluate the various factors which are involved.

A. J. Hulse: Mr. Johnson's conclusion, that increasing the distance from the dumping point of the skip to the closed position of the large bell, has no detrimental effect on the furnace lining is in accord with

results of an investigation we made at South Works about two years ago. I believe there are so many other factors which have a determining effect on lining life, many of which we know little about, that the dimension referred to can be disregarded in so far as consideration of lining life is concerned.

In comparing the lining life of various furnaces it is important to know whether they were actually blown out for relining or whether they were blown out for reasons of business conditions and upon inspection a decision made to reline rather than chance a failure on a blow-in. Under such conditions it is possible that considerable additional tonnage could have been made had the furnace been kept in blast.

An inspection of burnt line profiles and campaign records that were available in the Chicago district indicated that the condition of the furnace throat and particularly the brick immediately below the stock line wearing plates have a more important effect on furnace performance toward the end of a campaign than does the condition of the brick in the inwall above the mantle.

Furnace performance with regard to coke and flue dust will usually be found to remain normal as long as the brickwork at and below the stock line is in good condition. A good example of such a situation is the last campaign on No. 9 furnace at South Works. This furnace was blown out for business reasons late in 1937. She had water on the shell and it was known the lining above the mantle was rather thin. However, her coke rate and flue dust were what was considered normal and no consideration had been given to a blow out for relining. After being blown out, a preliminary inspection revealed that the brickwork above the mantle for a distance of some 18 ft. was worn to an extent that made it unsafe to even measure the burnt lines and make a comprehensive inspection. The throat of this furnace was in excellent condition and the stock line protection was so good that means were considered to support it and replace the brick below it to the mantle. However, the furnace was eventually relined from the mantle up. That is an example of good furnace performance with a good throat and a badly worn inwall.

We have many times experienced the condition where the inwall was in reasonably good condition, and the throat badly worn. Such a condition will usually show itself by increased coke and flue dust and very irregular furnace performance.

With regard to stove brick thickness, I believe with secondary cleaned gas it is feasible to go to a thinner brick section than the 2¼ in. mentioned by Mr. Johnson. This will depend on the type of checker construction.

J. G. West: Jr.: Anyone who has experienced a lot of changes in coking coals, different processes of coking and possibly the physical and chemical qualities of the other materials used, being irregular, will appreciate, the effort that Mr. Johnson has used to avoid breakage. There are plants in the Pittsburgh district that have to contend with severe breakages. Cases are known when using 100 per cent high volatile coals in the mixtures, that when the resulting cokes are submitted to tests, only 25 to 30 per cent remain on the 2 in. square screen. This lack of strength is directly reflected into a much lower pig output, with a lot of attending furnace troubles.

L. E. Riddle: I would like to know why the big bell hopper is not made larger. The one shown did not look very large. I believe the usual revolving tops are never made with hoppers that exceed 1300 cu. ft. capacity. I think we ought to get them up to say 1700 cu. ft. so that we can put about 100,000 lb. total stock on that large bell at once if desired.

A. G. McKee: Allow me to remark that although a furnace is tailor-made, without exception you have to make the furnace more or less conform to the well-founded opinions based on the experience of the man you are building for. In this case, the volume capacity on the big bell was kept down particularly in order to reduce the distance that the coke was dropped. You can't have your cake and eat it. You must decide between conflicting requirements, and while personally I should have liked to have had this volume capacity greater, still I think Mr. Johnson's judgment in the matter was excellent, as demonstrated by the excellent results which he is getting.

E. K. Miller: Mr. Riddle commented on the mixing of hot and cold blast. Twelve years ago when I was operating the Fairfield blast furnaces, we were running 1450 degree F. straight line heat on the furnaces and, at that time, the wind blown on the furnaces was 76,000 to 78,000 cu. ft. per min. The mixer valve was located between the stoves and the blast furnace. At times when we were using 1450 degree F. straight line heat, we carried, for periods of 48 hr., 1650 degree F. straight line heat.

However, I found that in using a mixer valve to run with higher heat, when the stove was changed the mixer valve was wide open for a short period of time in order to bring down the temperature of the hot blast to the temperature ordered and found that the tuyeres on the opposite side of the bustle pipe, from where the hot blast entered, looked very cloudy, while the tuyeres on the other side were clear. At that time, we decided to blow through two stoves at a time, and every hour a stove was changed. On the new stove going on, the cold blast valve was opened slowly on the hot stove, thereby allowing the mixer valve to open up only enough to line the heat going to the furnace. After the heat was lined, the hot stove cold blast valve, during the next hour, was gradually opened and the cold blast valve on the colder stove was closed at the same time. The furnace operated more smoothly and the burden ratio increased as high as 2.75 compared to 2.40.

At the Aliquippa plant of the Jones and Laughlin Steel Corporation, No. 3 blast furnace, which has a hearth diameter of 28 ft. 6 in., is operating at the present time and has produced to date approximately 2,070,000 gross tons without any repair work being made to the lining.

The No. 2 blast furnace at Aliquippa, having a hearth diameter of 21 ft. 6 in., finished a campaign in January, 1936, producing 2,087,000 gross tons on a lining. However, in 1930, after producing over 1,350,000 gross tons, the furnace was blown out and a 30 ft. patch was made in the inwall right above the mantle.

No. 4 blast furnace at Aliquippa works, which has a 27 ft. hearth diameter, produced 2,240,000 gross tons on a lining and was blown out in August, 1937, for

complete relining. However, during the campaign, this furnace had a small patch on a stock line.

In another article written by Mr. Johnson recently, I noted that the alumina in the slag on the new furnace was running approximately 14 per cent. I would like to ask Mr. Johnson whether he is running high alumina in the slag on the new furnace or on all of them.

H. W. JOHNSON: We prefer to keep the alumina in the slag from 13 to 14 per cent on all furnaces.

E. K. MILLER: You see quite a difference in the working of a furnace?

H. W. JOHNSON: No, we have run down to 11 or 12 per cent without noting much difference.

H. E. MCDONNELL: If I may be excused from making any comments on Mr. Johnson's excellent paper, I would prefer to hear some comments regarding stove dome temperatures. In the high capacity hot blast stoves operating on finely cleaned gas, what has been the experience as to maximum dome temperature that might safely be carried, also will 1¾ in. checker brick in the top courses safely stand the same operating temperatures as a 2½ in. checker brick?

MEMBER: In many cases, stove domes are limited to 2050 degrees F., either by automatic control, or manually from pyrometer indication. Experience seems to indicate that the thinner checker brick in the top courses stands up satisfactorily, although it might not be equal to the 2½ in. brick.

H. COPE: If I remember correctly Mr. Johnson's Table 4, where he compared the unscreened coke with the screened coke, there was at least 100 degrees blast temperature lower with the unscreened coke practice for the three months than with the screened coke. The question I would like to raise is: Was that deliberate, or was it found necessary?

H. W. JOHNSON: It was found necessary. We were trying to maintain the maximum blast temperature on the furnace at all times.

H. COPE: During the unscreened coke period, would not the furnace work smoothly on high blast temperature?

H. W. JOHNSON: The furnace would not take as high blast temperature during the period of unscreened coke. I did not include it in this table, but we also recorded the number of checks for hanging, and it did increase appreciably during the period the screens were not in operation.

FRED DENIG: I have read Mr. Johnson's paper with great interest, and I feel that he has made a notable contribution to the literature on the subject of blast-furnace design and operation. Mr. Johnson has investigated in great detail many outstanding points and he has given the greatest amount of discussion to coke.

Many authorities claim that the behavior of a blast furnace depends largely upon the character of the coke used. However, in this installation the coke to each skip is not weighed, although it may be weighed in the transfer cars. All the other raw material is carefully weighed and measured. The probable reason for not weighing coke is that its great bulk in comparison to the other materials would require a much larger lorry car. Also, variation in moisture in the coke has been given as another reason, but that item also applies to ore and stone. If it is worth while to weigh ore and limestone, it must be worth while to carefully weigh the coke. So far as the moisture is concerned, it is quite possible that there is more opportunity to control the moisture content of coke than of the other raw materials. Many blast furnace coke producers control their moisture within very narrow limits. It would be very interesting to examine records of operation of two similar furnaces operating on the same burden but one measuring coke by weight and the other by volume.

Mr. Johnson presents a good case for the removal of fines from coke, but it would have been more conclusive had he presented further data to show that other properties of the coke were the same in the periods compared. I strongly feel that Mr. Johnson should have added tumbler tests to items tested, and that perhaps he should have analyzed the problem along the lines that Robert W. Campbell carried out in a recent paper before a joint meeting of the Eastern and Western Blast Furnace and Coke-Oven Associations. In this work Mr. Campbell presented an empirical formula, developed by F. W. Wagner, based largely on experience. This formula read as follows, and from this formula he derived a factor known as the "physical fuel value":

EMPIRICAL FORMULA FOR PHYSICAL VALUE

$$P.F.V. = .6[A] + .2[B] + .1[C] + .1[(D)\ (100\% - E)]$$

A = Tumbler test = per cent on 1 in.
B = Shatter test = per cent on 2 in.
C = Porosity
D = Screen test = per cent total on 2 in.
E = Screen test = per cent on 4 in.

EXAMPLE (RAW COAL—COKE)

$$26.17 = .6[17.1] + .2[30.8] + .1[44.49] + .1[(56.5)(100 - 5.8)] = P.F.V.$$

Now it will be noted that considerable weight is given to the tumbler test. The results given by this formula show distinctly that as the physical fuel value increases the coke consumption per ton of pig iron was reduced on the blast furnace. It also demonstrated that the tumbler test had a great deal to do with and probably was the outstanding item in correcting the fuel consumption on the blast furnace. The tumbler test indicates the abrasion of the coke, its ability to withstand rubbing and degradation to dust. Experience has indicated on the blast furnace that too much fine, breeze, etc., are deleterious to furnace operation. Even if reasonably sized pieces are charged to the furnace and they readily grind to dust either by rubbing against other pieces of coke or against pieces of ore or limestone, the end result will be the same as if slugs of breeze were charged to the furnace.

The writer has private information that several other plants in this country are trying out the method of furnace analysis using the "physical fuel value" formula as set forth by Mr. Campbell and are obtaining very interesting results.

It is not amiss at this point to say that a furnace in the far West is using coke almost of the same size that

Mr. Johnson is removing from his furnace coke, and still is obtaining remarkable results. Although Mr. Johnson shows some advantage in the removal of fines from coke, he practically admits that this advantage is small:

"The coke bin and skip layout has operated satisfactorily and economically. The maintenance cost is low, as is the cost of disposing of the screenings. This is most important, as the margin of profit in screening coke for the blast furnace is not excessive, and an inferior design may result in such high costs that much of the profit disappears."

I trust Mr. Johnson can clarify this statement, inasmuch as it differs from his supporting data.

It has always been my belief that if the ratio of ore to coke could be accurately maintained much of the variation in blast-furnace operation could be eliminated. This is only another way of saying that coke must be uniform in all respects. That idea is not new, but if methods of sampling and testing are used which will satisfactorily show the uniformity of coke, then the blast-furnace problem could be more intelligently attacked. When sampling and testing methods are used which in themselves have large inherent errors, nothing but confusion can be expected, and that is the case in many instances today. Too often blast-furnace men are concerned with the size of coke cells when they should be concerned with the size of coke samples. Too often they are impressed with the results of a test when they should be concerned with the procedure for testing.

Mr. Johnson has tried to correlate his data and to correct information so as to obviate many of these discrepancies, and in this he is to be congratulated. However, in conclusion, I would recommend very strongly that Mr. Johnson give consideration to the tumbler test in his further studies.

J. C. BARRETT: For further discussion of Mr. Johnson's paper, I hereby give the comparison of the lines of Inland No. 5 and Ohio Works No. 2.

TABLE A

	Ohio No. 2		Inland No. 5
	Original	Repaired	
Height of furnace	104 ft. 6 in.	104 ft. 6 in.	101 ft.
Height of bosh	9 ft.	9 ft.	10 ft.
Height of straight at bosh	13 ft.	13 ft.	9 ft. 6 in.
Slope of stack	1.0625 ft.	1.0625 ft.	.949 ft.
Angle of bosh	80 degrees 32 minutes	80 degrees 32 minutes	81 degrees 28 minutes 9 seconds
Diameter of hearth	25 ft.	25 ft.	25 ft.
Diameter of bosh	28 ft.	28 ft.	28 ft.
Diameter of stockline	19 ft.	19 ft. 6 in.	19 ft. 6 in.
Diameter of big bell	14 ft.	14 ft. 4 in.	14 ft. 6 in.

Inland No. 5 has a good coke screening system and is quite like that recommended for Ohio No. 2 where the balance bin carries just enough coke for the skip and leaves the bin empty but will be immediately filled again with screened and weighed coke for the next skip of coke—working automatically. Filling is independent. Mr. Johnson has shown in his paper another example of the need of getting the breeze out of the coke which results in better tonnage and better quality of iron. He also shows what a remarkable coke he has to use, made of 70 per cent high volatile Kentucky coal and 30 per cent Pocahontas with a coke ash between 5 and 6 per cent. This is quite a contrast with the coke used in the Pittsburgh district of about 11 per cent ash. Comparison made between districts or furnaces should be made on pounds of carbon per ton of iron and not pounds of coke.

Mr. Johnson has done considerable work to overcome the breakage of coke as it is received at the stockline in the furnace. The Pittsburgh district has 100 per cent high volatile coal to produce coke and they do exceptional work in pounds of coke per ton of iron and could do better with 18 per cent sinter in mixture.

The No. 5 Inland furnace with its lines, size and equipment is excellent. The furnace is filled with a double skip. The skip discharges the material first on one side and then the other of the receiving hopper. And Mr. Johnson says, "The small bell is loaded unsymmetrically." This introduces irregularity which is to some extent overcome by the revolving top. The single skip filling has less irregularity to be overcome by the revolving hopper. Another irregularity is overcome by having a coke bin of the proper size and shape so that when the coke is drawn from it the coke moves evenly in every part of bin and thus avoids segregation.

With a given stockline the best distribution of materials and the efficient reduction by the gas, experience has led us by trial and failure to find the right relations from which we may make a rule or law. Our operations are carried on with a very large per cent of Mesabi ore. The use of an entirely different ore mixture may lead us to a little different relation between the size of bell and stockline. The right relation is not based on bell clearance but on relation of area of bell and area of stockline. The Inland ratio 1.81 between the area of bell and area of stockline is close to the best practice and Mr. Johnson could find some very interesting information should he explore the top part of the furnace by using various sizes of charge placed on the big bell and dropped into the furnace, noting the time he keeps the bell open for discharge of the load. This should be done for more enlightenment for blast furnace men.

In discussing this paper I have assembled tests for making a comparison of CO and CO_2 in the gas taken from points 1 ft. apart from wall to center of the furnace, with stockline diameter ranging 17–20 ft., and with large and small charges of burden.

This exhibit of CO and CO_2 and the ratio of same leads one to see that the zone of 1 ft. and 2 ft. from the wall is not doing its share of reduction and the centre of the furnace is about the same in work. This exhibit is to help us think it through. One way to improve this gas condition is a large charge so it will spread ore material over the whole area of the stockline. These tests were taken from each foot from the wall to the center of the furnace. Tests taken every 6 in. consume too much time and since the furnace is moving the more time used on the test, the more error. The tests should be made quickly. Inland No. 5 stockline is 19 ft. 6 in. and the area is 298.6 sq. ft. and a foot of stock would be 298.6 cu. ft. The charge of material is 10,000 lb. coke, 23,000 lb. of ore and sinter and about 4,000 lb. of stone, approximately 37,000 lb. Each cu. ft. of mixed stock

TABLE B

"D"	Wall	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.	10 ft.	Remarks
CO, per cent	26.5	24.3	23.0	23.4	21.7	21.6	21.9	22.3	23.1	23.1	23.8	20 ft. diameter stockline
CO_2, per cent	13.0	15.5	16.9	17.6	18.4	18.7	18.6	18.6	18.4	18.3	17.9	Area 314 sq. ft.
Ratio	2.05	1.61	1.38	1.30	1.21	1.16	1.18	1.21	1.26	1.28	1.36	14 ft. 8 in. diameter bell
												Total charge 85,000 lb.

"F"	Wall	6 in.	1 ft. 6 in.	2 ft. 6 in.	3 ft. 6 in.	4 ft. 6 in.	5 ft. 6 in.	6 ft. 6 in.	7 ft. 6 in.	8 ft. 6 in.	9 ft. 6 in.	
CO, per cent	27.9	27.2	25.5	24.1	22.5	22.0	21.9	22.5	22.5	23.6	23.2	19 ft. diameter stockline
CO_2, per cent	12.4	12.8	14.4	15.9	17.5	17.8	17.9	17.8	18.1	17.8	17.6	Area 283.5 sq. ft.
Ratio	2.32	2.21	1.87	1.62	1.31	1.24	1.23	1.27	1.25	1.35	1.33	14 ft. diameter bell
												Total burden 80,000 lb.

Ohio No. 2	Wall	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.	9 ft. 6 in.	
CO, per cent	23.0	21.8	21.7	22.2	22.6	23.4	24.3	25.8	26.0	25.4	25.6	19 ft. diameter stockline
CO_2, per cent	17.9	19.0	19.2	18.9	18.7	18.2	17.4	16.1	15.6	15.8	15.8	Area 283.5 sq. ft.
Ratio	1.3	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.7	1.6	1.7	14 ft. diameter bell
												Total burden 80,000 lb.

Inland No. 5	Wall	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.	10 ft.	
												19 ft. 6 in. diameter stockline
CO, per cent	30.6	26.6	22.6	21.6	21.2	21.0	21.5	23.4	26.2	30.5	31.8	Area 298.6 sq. ft.
CO_2, per cent	9.6	13.4	17.4	18.1	18.6	18.8	18.2	17.0	14.9	11.3	10.0	14 ft. 6 in. diameter bell
Ratio	3.19	1.98	1.30	1.19	1.14	1.12	1.18	1.38	1.76	2.70	3.18	Total burden 37,000 lb.

Inland No. 2	Wall	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	8 ft. 6 in.	Remarks
CO, per cent	31.2	26.8	24.5	23.0	23.7	24.7	29.9	36.4	39.6	41.5	
CO_2, per cent	8.6	12.7	14.7	16.7	15.7	14.7	9.9	4.7	1.35	.75	From H. W. Johnson's Table 10
Ratio	3.63	2.11	1.66	1.37	1.51	1.68	3.02	7.83	30.0	55.0	

South No. 4	Wall	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	8 ft. 6 in.	
											From Kinney paper No. 442
CO, per cent	29.9	29.5	26.7	21.1	24.5	24.2	24.8	26.4	33.6	35.3	17 ft. diameter stockline
CO_2, per cent	10.7	10.8	13.3	17.1	16.2	16.5	15.6	15.3	7.9	6.9	Area 226.98 sq. ft.
Ratio	2.7	2.7	2.0	1.2	1.5	1.5	1.6	1.7	4.2	5.1	13 ft. diameter bell
											Total Burden 37,000 lb.

would be 95 to 100 lb. The 37,000 lb. would be 370 cu. ft. The total charge spread evenly over the 19 ft. 6 in. stockline area would be a depth of about 1.3 ft. A charge of 37,000 lb. from the big bell against the wall would not give a spread of ore wide enough to put much in the center of the furnace, consequently the center of the furnace does little reduction or work and this leads one to see the need of a large charge for the size of the furnace. With the apparatus Mr. Johnson has, it would be fine to see him explore more into the various possibilities for more efficient furnace operation. 10,000 lb. of coke should use more than 23,000 lb. of ore burden with 18 per cent sinter.

H. W. JOHNSON: The author wishes to express his appreciation to each individual who entered into the discussion. In place of individual comments, the discussion has been grouped into the four general heads of coke, operation, radial surveys, and construction.

COKE

It is to be regretted that tumbler and shatter tests were not available for the period described in Table 3 when the test run was made on the furnace with and without coke screens. However, the coal mixture, the coking time and the manufacture were all constant, so it can be assumed the coke was constant. During this period the screens were not in operation, and the other furnaces were not at the time equipped with any device for screening coke, so the tests represent the coke going into all of them. This coke was of about the same size as reported by L. E. Riddle; he stated that their screen tests show 42 per cent on a 2 in. screen. The daily screen tests of the coke taken at the skips showed that the size was constant throughout the period. The screen tests in Table 4 show that 40.49 per cent of the coke going into the furnace was over 2 in. in size.

It is probable that too much attention is paid to the size of coke, and not enough to other factors. There is a feeling that improving the facilities for removing fines or small size coke at the skips will be a panacea for all blast furnace ills. A certain amount is to be gained from such an installation, and no more. The profit can be determined roughly by using the data in Table 3 and applying it to the conditions that obtain at any plant at a given time. Since these conditions vary not only from plant to plant, but from one time to another, the margin of profit will also vary.

In concentrating on the size of coke as indicated by screen test data, we can easily overlook other factors of major importance, particularly when comparing results on different furnaces. We have used up to 33 per cent of coke that was through a $1\frac{1}{8}$ in. screen, and on a $\frac{5}{8}$ in. screen, together with 100 per cent Lake Superior ore burdens, but with less than normal wind. It was not possible, however, to use it on full wind. A furnace may operate successfully on small coke, for example the one in the far west mentioned by Denig. First, while the coke may be small, the other physical

properties such as "its ability to withstand rubbing and degradation to dust" (Denig) may be satisfactory. Moreover, the furnace operates on hard ore, crushed and sized. Additional voids are therefore uniformly distributed in the furnace so as to create lower gas velocities through the stock column than those in a furnace operated on any Lake Superior ores.

The relative advantages of charging coke by weight or by volume have been the subject of much discussion. It may be charged by volume if the coke produced is constant; each skip load will contain the same number of pounds of fixed carbon, and there will be no need to weigh it. Weighing the coke in the charging operation introduces an additional handling which causes just so much more breakage.

OPERATION

It was unfortunate that it was necessary to present this paper so early in the campaign of No. 5 furnace because operating data under different conditions would have been available later. The three months of operation during which the furnace averaged over 1000 long tons per day represents its performance when blown at a rate of 60,000 cu. ft. of wind per minute, with no iron produced that was over .035 per cent sulphur. During this period the cost and quality of iron were of major importance. Recently, there has been a need for more tonnage and the wind has been increased to 63,000. Following is the operating data for the last 10 days of November 1939:

Daily production, long tons	1112
Pounds of coke per gross ton of iron	1545
Scrap charged (per cent of total burden)	4.17
Sinter charged (per cent of total burden)	18.04
Average sulphur in iron, per cent	.02
Average silicon in iron, per cent	1.04

No iron produced during this 10 day period was over .035 per cent sulphur.

The amount of blast heat used on the furnace is largely determined by what it will take without hanging. Following are typical monthly averages:

April 1939	1112 degrees F.
May 1939	1132 degrees F.
June 1939	1221 degrees F.
July 1939	1209 degrees F.

It was stated that the coke unit was 10,000 pounds and so a burden of 23,000 is very low, indicating inefficient operation. The coke unit figure is an assumed one which has no importance. Efficiency of the furnace should be judged entirely by the coke consumption figures presented. The actual coke unit for May 1939 was 9123 lb., the average burden 22,755 lb., so the average coke ratio was 2.50. The author regrets introducing this confusion.

RADIAL SURVEYS

It was with some apprehension that the data on radial surveys in connection with furnace operation of No. 5 furnace was introduced, because it is impossible to know whether a survey actually or nearly represents the condition within the furnace.

Data were presented in the paper (Figures 5 and 6) which indicate that the surveys are relatively accurate. This does not mean they are absolutely accurate. Because there is so much uncertainty, any such data should be examined critically. After taking over 100 of such surveys, we can be confident that they do not represent the condition accurately, and radial surveys can certainly not be used at present as a measure of furnace efficiency. It is best to measure this efficiency by pounds of coke or carbon consumed per ton of iron produced.

In Figure 7 were presented surveys on No. 2 furnace showing only a few per cent CO_2 near the center of the furnace. It was pointed out in the oral discussion that this was very wasteful. Actually the furnace operated satisfactorily during the period. By certain changes, we have raised the CO_2 content in the central zone up to 11 to 14 per cent so that the surveys look much more satisfactory. However, the furnace did not operate either smoothly or efficiently, and we soon changed back to the open center.

Mr. Barrett presents some surveys showing the CO_2 content very high from the wall to the center of the furnace. One survey used in his discussion is the same as one made on Ohio No. 2 which he included in his paper "Design and Operation of a Modern Blast Furnace."[1] In that paper, this survey is compared with one made by S. P. Kinney[2] as follows:

Ohio No. 2 Furnace 19 ft. stock line Plane 1— 4 ft. below stock line		South No. 4 Furnace 17 ft. stock line Plane 1— 4 ft. below stock line	
Distance from inwall, ft.	*Per cent CO_2*	*Distance from inwall, ft.*	*Per cent CO_2*
0	17.9	0	10.7
1	19	1	10.8
2	19.2	2	13.3
3	18.9	3	17.1
4	18.7	4	16.2
5	18.2	5	16.5
6	17.4	6	15.6
7	16.1	7	15.3
8	15.6	8	7.9
9	16.8	8.5	6.9
9.5	15.8		
Top gas	15.6	Top gas	14.7

Since the top gas is a mixture of the gases from all of the annular rings it would be expected that a survey which accurately depicts the condition within the furnace will have some rings in which the CO_2 is less than in the top gas and some in which it is more. This is true in the survey presented by Kinney. However, in the survey presented by Barrett the CO_2 in the top gas is less than it is in the individual result for any of the annular rings.

Some other method of charging may result in more efficient operation of this or any other furnace. But at

(*Please turn to page 57*)

[1]Iron and Steel Engineer, February, 1939.
[2]South Works No. 4 furnace.

CLEVELAND DISTRICT SECTION
ASSOCIATION OF IRON AND STEEL ENGINEERS

Inspection Trip

to the

REPUBLIC STEEL CORPORATION

ELECTRIC FURNACES AT CANTON, OHIO

STAINLESS COLD REDUCING AND FINISHING, MASSILLON, OHIO

BUSES WILL LEAVE HOTEL COURTLAND AT 12:30 P. M.

Tuesday, May 28, 1940

HEADQUARTERS

HOTEL COURTLAND

CANTON, OHIO

TECHNICAL SESSION

8:00 P. M.

Papers treating of problems in the production of stainless steel and in the manufacture of stainless clad plate will be presented.

CHAIRMAN

I. N. TULL

ELECTRICAL SUPERINTENDENT

REPUBLIC STEEL CORPORATION

CLEVELAND, OHIO

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STEEL CONDITIONING

With the Oxy-Acetylene Method

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This paper is the third of four forming a symposium on the conditioning of steel surface. The first and second papers appeared in the March issue of the IRON AND STEEL ENGINEER, and the last paper will appear in a future issue.

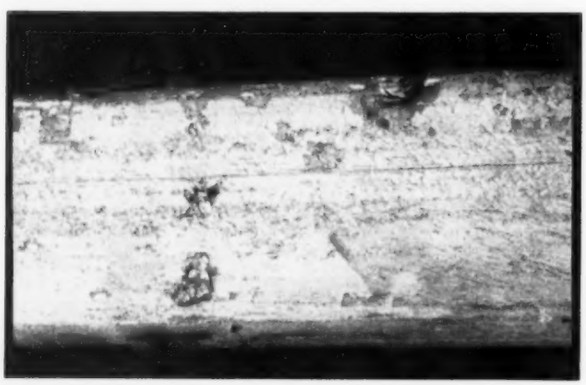
Presented before A. I. S. E. Annual Convention, Pittsburgh, Pennsylvania, September 26-29, 1939

▲ IN the production of slabs, blooms, billets, and other semi-finished rolling mill products, the surfaces of these products generally contain numerous defects, referred to, in the steel mills, by various names, such as, seams, slivers, snakes, stars, crow feet, dog face, scabs, laps, scale, spongy edges, etc., some of which are shown in Figure 1. A majority of these defects are on or near the surface of the steel and often have the appearance of only being light hair line seams, light scale, etc., but which in most cases must be removed from the semi-finished materials, in order that a quality finished product can be obtained therefrom, and if not removed generally are the source of defective or scrap products.

The conditioning of the semi-finished materials preparatory to the finish rolling has always been and perhaps always will be a major problem for most of the steel producers.

In the past, practically all of the defects mentioned were removed by either manual or mechanical chipping or, in some cases where steels were too hard to chip, by grinding. Numerous studies were made, along many various lines of thought, in order to try and increase the low efficiency of hand chipping operations, thereby reducing the corresponding high cost per ton involved. Considerable success was derived from the results of these studies. With the ever increasing demands of the customer and labor on the producer, costs still ran from $4 to $8 per ton, the average generally pressing on the higher figures, and the cost, of course, depending on type of steel and class of conditioning given. The high cost was not only contingent on the slowness of the operation, which necessitated many hours of manual labor, but also on the high cost of maintenance and replacement of essential equipment used. It cannot be denied that hand chipping was and still is a crude, slow, expensive, and unsatisfactory method of steel conditioning and has only existed because the producer had nothing better to switch to.

FIGURE 1—Surface defects in semi-finished steel products may take various forms, and must be removed before subsequent rolling.



Reaching out for other means to try to speed up production and reduce high chipping costs, swing grinders were brought into the picture. However, the vogue did not last long, due to an increased, instead of a decreased cost, plus the inability of the wheel to go after deep cracks and defects and the restricted limit of its portable flexibility, necessitating high material handling costs. The swing grinder has survived, however, in the tool and alloy steel field, primarily because these metals are too hard for cutting tools, the blooms and billets are generally smaller and because of the quality of conditioning demanded by finishing mills. Cleaning costs by this method vary from $12 to $20 per gross ton with the average around $15. Swing grinding is at present, and undoubtedly always will be, the most costly method of cleaning steel, mainly due to slowness of the operation which makes labor costs excessive, plus high cost of grinding wheels.

In further efforts to cut down exorbitant hand chipping costs, steel producers have spent large sums of money experimenting with various methods of mechani-

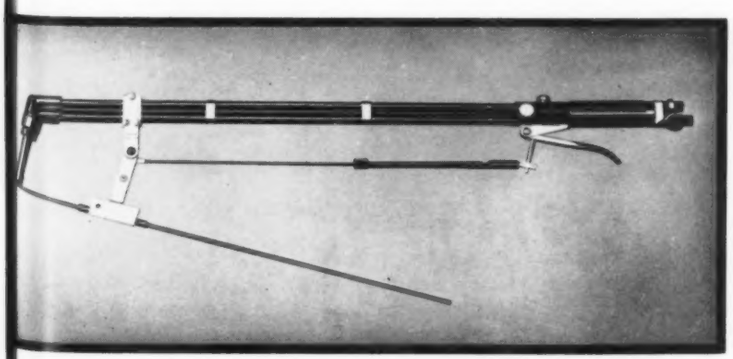
cal chipping. Mainly, the experiments have consisted in the use of large and expensive machines employing machine tool principles, such as, milling machines, planers, lathes, etc. These machines embodied motors and gear-driven mechanisms effecting a forward movement on surface of material. The main thought, of course, behind the development was the idea of a machine that could be manipulated in three dimensions at the operator's wishes. Some of these machines did offer some relief over the hand chipping, but all of them have certain general disadvantages which hinder them from being the relief expected. One of the main disadvantages is their dimensional limitations. If the machine is sturdy and big enough for ingots, blooms, and slabs, it is far too cumbersome for the working of billets. Other disadvantages are the slowness of the operation, the quality of the work done (which is such that on high class materials, hand chipping often is used after machine cleaning to smooth up torn surfaces). On top of this, is the high cost of operation and high maintenance cost of tools and the machines. The initial cost of installation of these machines plus required auxiliary equipment for handling purposes runs from $25,000 to $75,000.

DESEAMING OR SCARFING

A newer method of cleaning semi-finished steel is deseaming with the oxyacetylene torch, or what is commonly known as scarfing. Actually scarfing is burning out enough of the steel in the vicinity of the defect so as to remove same and still leave the surface of the steel in such a condition that it can be rolled into satisfactory finished product. The oxyacetylene method of removing defects from the steel is as follows.

Generally, six oxyacetylene flames are produced in a specially designed and constructed deseaming torch, Figure 2. These are called the preheating flames and they raise the surface of the steel to kindling temperature and maintain this temperature. Then a stream of pure dry oxygen, called cutting oxygen, is turned on and applied to the steel horizontally along surface of material by an experienced torch operator or scarfer. The cutting oxygen combines with the preheated steel and quickly removes a thin layer of material from the surface and in this manner the defect is eliminated leaving good sound steel.

FIGURE 2—Steel is conditioned by the oxyacetylene method using a specially designed deseaming, or scarfing, torch.



The foregoing describes in brief the hand deseaming or scarfing operation whether it is used either for individual defects or for 100 per cent surface removal.

The use of deseaming or scarfing for removal of defects from the surface of ingots, slabs, blooms, and billets has increased rapidly during the past few years. In fact, the operation has increased so fast that the tonnages now cleaned by this method far exceed that which is cleaned by chipping. It is no exaggeration when it is said that scarfing is revolutionizing steel cleaning practice.

For a period after its introduction, the deseaming operation was only considered an auxiliary to hand chipping and only used on salvage or reclamation work for cleaning of badly cracked ingots, blooms, and slabs, which otherwise were scrapped due to prohibitive chipping costs. The demand for large tonnages of conditioned slabs for the large capacity mills, plus the trade demands for practically over night shipment of their orders, overtaxed available chipping facilities, hence steel producers turned to the scarfing operation, not only because of its capability to condition large tonnages of steel rapidly but best of all to do it economically. Large economies both in money and time are being realized by concerns using this operation. The operation is from ten to twelve times faster and at least 50 per cent cheaper than pneumatic or hand chipping. While there is a large saving in costs on any comparable cleaning, the value of scarfing to the user increases as the amount of work per ton conditioned increases. Since the process is speedy, considerable time is saved and the processing from the pouring of the ingot to the finished product is materially shortened.

Torch deseaming or scarfing abolutely insures the removal of defects. Imperfections in the steel show up while the cut is in progress. The torch operator or scarfer through special goggles sees the defects as irregularities in the cutting oxygen stream. Even the most minute defects are readily discernible by this method. Contrary to what is generally believed to take place, scarfing does not weld up small seams, but instead actually opens them up after a pass with the torch. These cracks are opened up by the heat generated when the steel and oxygen burn during the cut. The size of the material and the speed of the operation preclude any possibility of any welding action. The speed of the operation 50–100 ft. per min. also precludes any possibility of decarburization. The surface of finished cut has a light flaky oxide which can readily be brushed off with a wire brush. The scarfed surface is clean and bright and inspection thus facilitated.

Development of deseaming techniques for various size sections and grades of steel along with better torches and tips plus auxiliary starting equipment (by which steel is preheated for the start, very nearly instantaneously) has advanced to the point where today deseaming is being done on practically all grades of steel which burn under an oxygen stream and in all sizes down as small as 1½ in. x 1½ in. billets, both on plain carbon and alloy steels. The foregoing holds good for practically all grades formerly cleaned by chipping and a great number of grades formerly "swing ground." This includes practically every S.A.E. grade of steel with the

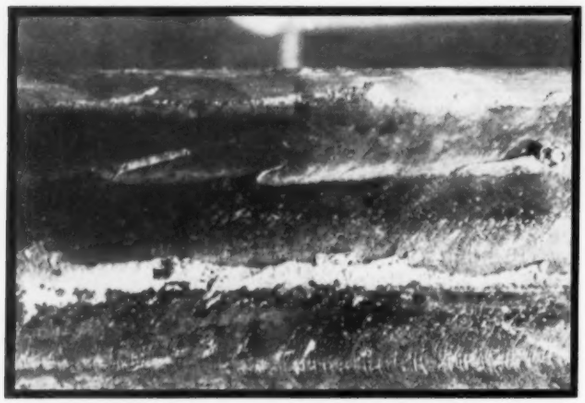


FIGURE 3—This view of a cut made by a scarfing torch shows undesirable fins at the sides of the cut.

exception of the corrosion and heat resisting steels. Also many special grades not listed on the S.A.E. lineup can be very readily cleaned by the scarfing operation.

Deseaming technique involves a knowledge of oxy-acetylene torch manipulation. In selecting operators, it is best to select men who are familiar with steel defects, rather than men familiar with oxyacetylene torch equipment and manipulation. Facility to handle the torch is in most cases very readily acquired and in a few days time the average man will produce satisfactory work.

The first step in the operation after the equipment is set up and ready for use, is the preheating or "kindling" of the steel. Preheating is raising the temperature of the steel high enough and maintaining it so that the oxygen stream can combine with the heated surface of the metal and thus the cut or scarf is started.

Starting of the cut is facilitated, and elimination of any guage at the start is assured through use of the starting rod feed device, Figure 2. This attachment feeds a $\frac{3}{16}$ in. low carbon rod through the preheating flames into the oxygen stream and furnishes "kindling" for quick starts. Starts are now practically instantaneous. Quick starts are very desirable at any time for any class of work, due to the labor and fuel economy, but are especially desirable when working on billets where only "spot" work is generally prevalent. Advantages of the starting rod feed device are less pronounced in ingot, bloom, and slab scarfing where subsequent heavy reductions in the rolling mill make the quality of the start less important.

Aside from the skill of the operator in torch manipulation, the scarfed surface quality depends wholly on the proper positioning of the torch to the steel surface and the selection of suitable equipment, operating fuel pressures, and layout. The torch must be capable of delivering a suitable flow of fuel gases (acetylene and oxygen) so that the surface being removed is completely oxidized and not blown to the sides of the cut to form partially oxidized ridges of steel commonly known as fin, shown in Figure 3.

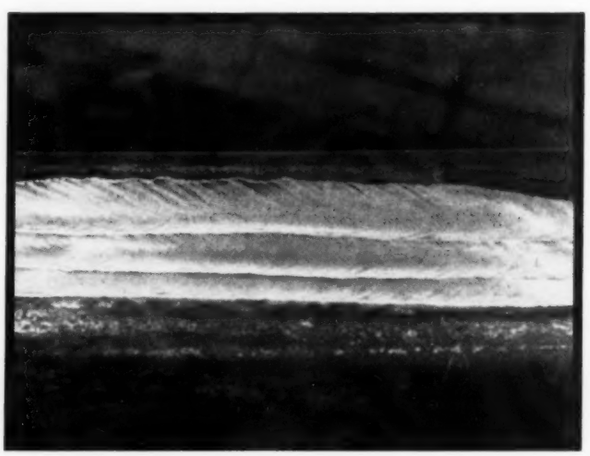
Fast shallow cuts with the torch inclined to the right of the path of travel produce cuts without the high intervening ridges and thus keep the slag moving away from the surface already scarfed. A series of parallel cuts thus can be made, leaving a bright, clean surface, free of fin and which can easily be inspected for any remaining defects, (Figure 4).

In order to take full advantage of the speed of the deseaming torch, very careful consideration must be given to the layout used. Material handling, preheating, inspection, reinspection, and gas supply should not be allowed to interfere with the torch operators. Fuel gases (oxygen and acetylene) should be piped from a central source of supply to required number of operating stations conveniently located along the deseaming beds. Ample crane facilities for handling materials to and from beds and for turning of large sections is very important. In laying out scarfing beds, the placing of materials and direction of the deseaming should allow a number of torch operators, inspectors, helpers, etc., to work simultaneously without interfering with each other. Ingots, blooms, slabs, and large billets are generally scarfed while resting on low supports laid on the ground. The yard should be laid out with several parallel beds. Operator works on the first bed and then moves to another one. While the operator is working on one bed, inspection, marking, material handling, etc., is being done on the adjoining beds, (Figure 5).

As the operator moves from bed to bed, he is followed by a helper who removes slag and assists in turning of materials. With a proper layout, plus adequate inspection and crane facilities, large tonnage outputs are possible from fairly small layouts.

In ground scarfing, the 36 in. torch is preferred as it enables the operator to walk on the material when scarfing slabs and large billets which is conducive to uniformity of the scarfed cut and to operator's efficiency. In deseaming billets of small cross section area, it is preferable to place the billets on benches or tables about 30 in. high. This method is conducive to efficient inspection and allows the operator to hold torch in a comfortable waist high position. Each operator generally

FIGURE 4—This series of parallel cuts shows a resultant bright clean surface, free of fin.



handles two adjacent beds working from both sides of each bed. The procedure here is the same as for ground scarfing, *viz.*, while the operator is working one bed, cleaning, marking, inspection, handling, etc., is being done on the adjacent beds without interference from torch operator. Scarfing torches not over 30 in. in length are preferred for bench scarfing because of their handling flexibility, and lightness, which reduces operator fatigue and allows operator closer inspection of the work while scarfing.

A high type of operator and inspector should be used for small billet deseaming so as to avoid needless removal of good metal and the possibility of not having full section from finishing mill.

The most recent development for deseaming billets of 2½ in. square and under, of equipment now available, far exceeds the performance of the chipping chisel in every respect. This equipment works at a speed of 50 to 60 ft. per min., makes a narrower cut, hence less metal loss, yet retains correct ratio of width to depth and reduces warpage of the section and fin to nil.

The flexibility of the deseaming torch is such that several plants are using the process for hot scarfing of large defects from blooms, slabs, etc., at the mill while material is in process of being rolled. The operator is stationed in a suitably protected pulpit at some convenient location along side of roll tables, wearing special clothes for personal protection, such as asbestos face shield, gloves, etc. He operates the torch through a slit in pulpit sheathing and is able to remove visible large defects from steel as it travels to next operation. Torches, 72 in. or longer, are generally used for this work. In plants where this type of deseaming is applicable, the large economies available are plainly self evident.

The cost of torch deseaming or scarfing per ton of steel will, of course, differ in various plants, depending upon several conditions mainly: steel quality, type of steel, section size, class of conditioning given, labor rates, handling and inspection.

FIGURE 5—The layout of scarfing beds should be such that the various operations may proceed without interference.

SCARFING COSTS

To quote any exact cost per ton figures for scarfing as compared to other cleaning methods would be impossible except in certain cases where the steels worked are identical in every respect. The final answer for the various plants concerned is the overall resultant economies obtained by the use of the scarfing process over the prevalent method used. Typical economies obtained with scarfing over hand chipping under various quality conditions are shown in the figures given in Figure 6.

The foregoing figures are not for any given condition but are the overall average condition for the year in the plants, regardless of the variations in class of conditioning, grade of steel or size of section.

Torch deseaming when compared to chipping offers several advantages, the most important being as follows:

1. Speeds of at least ten times faster resulting in lower conditioning costs.
2. Ability to salvage many stocks which formerly were scrapped due to prohibitive cleaning costs by any other method.
3. A reduction in inventory, stock handling facilities, in delays in assembling stock for rolling mill schedules, thus expediting shipments to customers.
4. The facilities to condition blooms, bars, billets and slabs, to insure perfect quality surface when reworked to finished products.

METALLURGY OF DESEAMING

The removal of defective surfaces by the use of oxy-acetylene flame deseaming or scarfing torch from higher carbon, alloy and tool steels involves some metallurgical factors, which if not taken into account, will result in the failure of the operation.

The rapid heating of the steel surface by the preheating flames and by the heat of the oxygen-iron reaction can cause a change in the structure at the surface with resultant hardness. The hardness developed is governed by the analysis of the steel and the same properties are present in the scarfed surface as would be developed by a hardening treatment. As an illustration, take a 1 in. round bar and heat one end, so that it will be above the critical temperature and quench. There will be a gradual change or graduation from the maximum hardness and structure from the heated and quenched end

to the unheated end. This graduation takes place on the steel surface on scarfing to approximately .015–.025 in. depth, depending on the character of the steel.

We are familiar with the fact that after quenching a steel, it is necessary in most cases to draw or reheat the steel, in order to relieve the strain set up by quenching. This factor is applied to scarfing analysis of this type by preheating the billet before scarfing. This preheating may be likened to a drawing operation as it is a means of developing a more tempered condition in the surface of a scarfed billet. The higher the preheat, the more tempered structure is developed. The preheating of the steel to a low temperature will reduce the hardness and relieve the mechanical strain. Pit annealing after rolling will not substitute for preheating before scarfing. Pit annealing will only insure against transverse cracking of the steel when subjected to the high torch temperature, but not the lace curtain effect obtained after scarfing. Preheating is the only insurance at the present time that will overcome the "lace curtain" defects. Should the billet crack in a transverse direction, the strain set up in prior rollings has not been properly relieved by suitable cooling from the mill.

Pickling of scarfed steel should be carried out very cautiously as the action of the acid coupled with the temperature of the pickling solution will attack the hardened area, developing an "alligator hide" type of defect on highly strained surfaces. On preheated billets, this condition is eliminated as the scarfed surfaces are not in a highly strained condition. This method can be used when in doubt, as a check to determine whether the steel was properly preheated.

The conditions surrounding the rolling mill heating furnace determine the proper procedure to be followed on the various analyses, in preparing the steel surface by scarfing for the mill. By proper handling of the steel for this mill, the steel will carry through the warming zone of the furnace and pass through the critical range of the steel into the austenitic state without any relief occurring. If it were possible to examine the surface structure at this time under the microscope, there would be no difference noted from that of a chipped, ground, or machine chipped billet.

FIGURE 6—These typical figures afford a comparison of conditioning by hand chipping and hand scarfing.

TYPICAL COMPARISON OF YEARLY DESEAMING AND CHIPPING COSTS PER GROSS TON

PLANT NO.	KIND OF STEEL	CHIPPING		DESEAMING	
		MAN-HRS.	COST	MAN-HRS.	COST
1	CARBON	.38	$1.58	.11	$.43
2	ALLOY	3.00	$3.71	.54	$2.83
3	CARBON & ALLOY	2.22	$2.74	.19	$.71

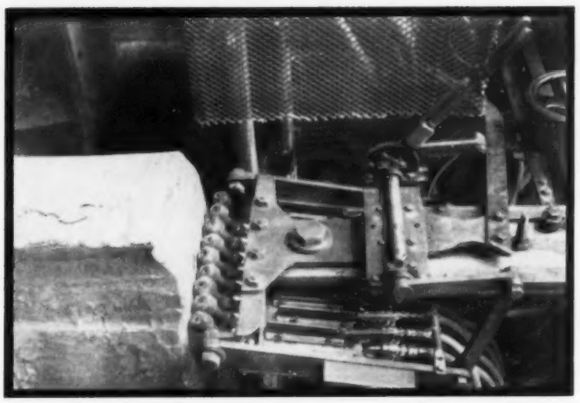


FIGURE 7—Multiple-torch assembly for mechanical scarfing is made up of sufficient tips to cover the width of stock to be desurfaced.

Stress relief cracks may be developed on the surface of the steel, either from cooling after improper scarfing procedure or on heating up in the rolling mill furnace. This relief cracking is discernible in the roughing line of the mill, as cross checking and same will also carry through to the finished size in a defect known as "crows feet." This condition can only be eliminated by preheating before scarfing. Below normal or freezing temperature of the steel must also be compensated for, or a lower range of analysis must be preheated in cold weather.

Deep gouging or improperly flared out cuts on some mills will not fill out and will cause defective material, hence should be avoided especially on material with small cross section area. The partly oxidized material commonly known as "fin" remaining on the billet will carry through to the finished product and appear as scabs and slivers if the rolling mill furnace does not have the ability to scale them off. When this is the case, care must be taken in scarfing to insure a minimum of fin. Types of steel having percentages of nickel, molybdenum and copper, are very susceptible to "finning," especially in the low carbon ranges, as these elements resist oxidation. The right type of operator, by using proper torch technique, equipment, and fuel pressures, can keep the amount of fin made to practically nil. In certain mills, due to heating and rolling limitations, it is necessary to remove fin if any is produced. All these factors must be taken into consideration and applied to each mill individually in order to produce 100 per cent surfaces on finished products.

The question always arises with novices in deseaming of the possibility that seams may be overlooked on the material on the premises that scarfing covers up defects. Defects missed can be seen on any scarfed surface. As stated before, the scarfer can tell by the torch flame whether the defect has been removed.

In scarfing of blooms and ingots the tenderness of an as-cast structure must be realized. Ingots and blooms should come to the torch from annealing or bury pits, warmer or mill with sufficient temperature to insure

against stress relief cracking. The proper handling procedure can be gauged by the analysis.

Due to the newness, plus the usual resistance accorded a new procedure, often defective finished surfaces are attributed to the fact that the semi-finished material was scarfed. It is well to point out at this time, in view of the success of deseaming of high carbon and alloy steels for the past few years, that should the defective surface of the finished product be attributed to deseaming, the improper handling of the material some where along the line should be searched out and remedied rather than penalize the deseaming operation. Many tests on various types of steel have been made and results have shown, both from mill inspection and laboratory checks, that the product from properly prepared scarfed materials is in all ways comparable to the product of materials cleaned by any other method.

MECHANICAL SCARFING

The need for a rapid and inexpensive means of completely removing the surfaces of steel stock, either cold or at rolling heat, in the intermediate stages of processing has long been recognized by the steel industry. The extension of the principle of oxyacetylene torch deseaming to include mechanically-operated multiple torch equipment, capable of desurfacing or skinning one or more surfaces of the steel stock with each pass provides the sought-for answer to this problem.

The multiple torch oxyacetylene skinning process is readily adapted to the various sizes of steel stocks and to the differing conditions under which they must be desurfaced. Whether the stock be billets, blooms or slabs, and whether the desurfacing must be done on the cold stock after intermediate inspection for surface defects, or on the hot stock leaving the blooming or slabbing mill, the process of machine torch desurfacing can profitably be applied.

While the basic principles of machine desurfacing or "scarfing" remain the same each mill presents its own production problems, hence the machine must be designed to afford the simplest, most efficient and economical operation under existing conditions. To fit into the production lines of the steel mill, a series of machines have been developed, each especially designed for its specific operation. The element common to this machine design is the multiple torch, held and positioned in relation to the surface to be removed. This multiple torch is designed for mounting either on a moving carriage to desurface one or more entire sides of the steel stock with each movement of the carriage, or in a fixed position on the mill runout line, desurfacing the stock as it moves forward on the roll tables.

The multiple-torch assembly is designed to permit simultaneous operation of sufficient tips to cover the width of the stock to be desurfaced. Each desurfacing tip produces a scarf approximately 1½ in. in width, nine tips sufficing to desurface the side of a 14 in. bloom. (Figure 7)

The number of tips operated will depend on the stock width. They are positioned in the multiple-torch assembly at a suitable angle to the horizontal. This angle can be adjusted according to the thickness of the surface layer to be removed. The tips are further positioned at a sharp angle to the direction of travel, the overlapping action of adjoining tips resulting in broad shallow scarfs. The sharp ridges between adjoining

FIGURE 8—The molten iron slag produced in mechanical scarfing is blown to one side by oxygen jets.

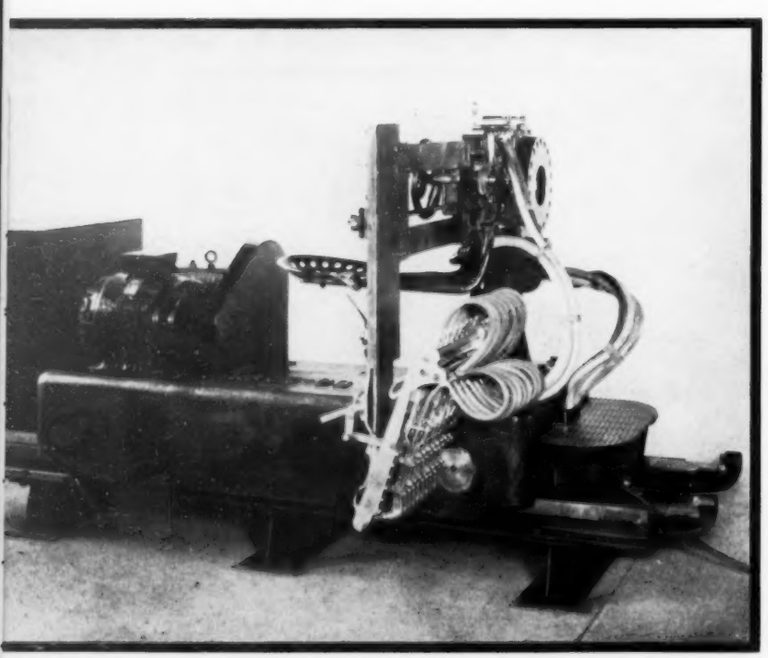
FIGURE 9—The steel surface resulting from mechanical scarfing is bright and free of slag, with broad shallow cuts.

scarfs that are formed when the tips point in the direction of travel are practically eliminated by this angular positioning of the tips and freedom from sharp metallic fins adhering to the scarf edges is assured.

The desurfacing tips are provided with protecting skirts to withstand the abrasive action incident to the operation. The torches are automatically adjustable to height, allowing the tips to follow the contour of a convex or concave surfaced bloom. Lateral adjustment of the multiple-torch assembly on the machine carriage enables the operator to follow the surface of a crooked or twisted bloom without interrupting the desurfacing operation. As the multiple-torch assembly moves relative to the stock, the molten iron slag produced is vigorously blown off to one side of the stock (Figure 8) by the oxygen jets positioned at an angle to the line of movement. This prevents accumulation of slag ahead of the tips and interference with the proper functioning of the oxygen streams. The resulting surface is free of slag and bright, equal in quality to the product of the mechanical skinning tool. (Figure 9)

The carriage type desurfacing machine (Figure 10) is designed to remove completely at one pass a single surface of billets and blooms from six to fourteen inches or more in width. The multiple torch working head contains nine desurfacing torches, independently adjustable according to the width of stock to be conditioned. The working head is mounted on a carriage driven by an adjustable speed motor through a chain drive. Carriage speeds, in a continuous range from fifteen to ninety feet per minute, are obtainable. The carriage is equipped with magnetically-operated controls, and dynamic braking for rapid accurate positioning of the working head over the stock. This machine is provided with controls for raising and lowering the multiple-torch working head, and for moving the working head laterally to follow bent stock. Provision is also made for rotating the assembly in a vertical plane in order to follow twisted stock as well as for instantaneously positioning the torches to follow convex or concave surfaces.

FIGURE 10—This carriage type desurfacing machine is designed to remove a single bloom surface in one pass.



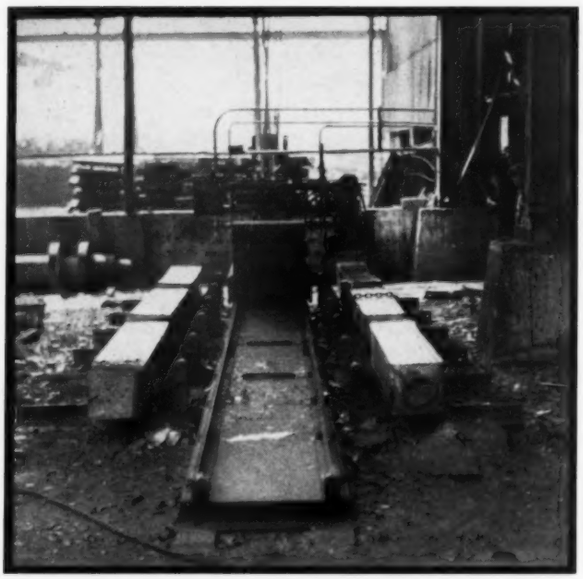


FIGURE 11—The carriage type machine moves along a track, desurfacing stock lined up on each side.

In operating this machine the stock is placed in lines parallel to both sides of the supporting track as shown in Figure 11. The operator, riding the machine, proceeds along one line, desurfacing the stock. At the end of the line of machine travel the multiple-torch working head is unlocked and swung to the other side of the carriage. The motor controls are then reversed, and the machine operated in the reverse direction, desurfacing the stock on the opposite side of the machine. During this period, the stock previously conditioned is turned to present an unscarfed surface for the next motion of the machine. The torches are angled to the direction of travel so that slag is blown away from the machine in both directions of travel.

The speed of travel generally used is seventy-five feet per minute when removing metal to a depth of three thirty-seconds inch. At this rate of speed, the output from this machine is limited only by the available stock handling facilities. Where desired, an L-type multiple-torch working head can be furnished to remove two sides of the stock surface at each pass. In general, the possible output from this machine with proper handling facilities is so far above the mill demand that a single-surface working head suffices, and has the advantage of reducing the peak demand for oxygen and acetylene. This machine will operate both on hot or cold stock.

Many adaptations of the movable carriage type desurfacing machine to specific steel mill problems have been considered. Surface defects are more prevalent in

slab edges than on the slab faces and result in sheets with imperfect edges. Edge scarfing the hot stock with desurfacing equipment (Figure 12) is the ready solution to this production problem.

The stationary, multiple face type of desurfacing machine (Figure 13) is designed to remove all four surfaces of blooms in transit from the shear on the rolling mill line, while at rolling temperature. It is placed in a definite position between the rolls of the rolling mill table. The blooms to be desurfaced pass through the machine at a constant level, and are skinned by two L-type multiple tip working heads. The width of the working heads is chosen for the range of stock size to be desurfaced, the machine illustrated handling blooms up to nine inches by nine inches. By simply replacing the working heads, blooms up to size of fourteen inches by fourteen inches or larger can be completely desurfaced in one pass through the machine.

The machine is traversed into operating position by motor drive, making it possible to position, or remove the machine, in accordance with production requirements. The positioning of the torches is also by motor drive, and through adequate electrical control they can be raised and lowered in operation or adjusted as may be required. Provision is also made to change the angle of oxygen stream impact so that the most favorable operating conditions can be secured for any desired depth of surface to be removed.

Two operators are required for the efficient handling of this unit. Each operator controls the equipment for the surfacing of two sides of a bloom, or actually one side and the top for the operator riding the machine, and one side and the bottom for the man positioned at the far end of the unit. All parts of the machine subjected to intense heat are water-cooled and when in operation, the parts and the operators as well are protected by shields. The operating speed with the bloom traveling along an accurately-guided path is one hundred feet or more per minute, depending on the grade of steel and the depth to which it must be desurfaced. Due to its design and to the efficient method of gas application, the depth of desurfacing can be accurately controlled with all of these machines.

HAND TORCH DESEAMING VS. MACHINE DESURFACING

Because of the high speed and the accurate control of the depth of surface removed, the cost of machine skinning is considerably less in relation to the area desurfaced than that obtained with hand deseaming. It is therefore frequently more economical to remove the entire stock surface with a desurfacing machine rather than merely to hand scarf the more defective areas. Machine desurfacing, allowing the removal of the entire surface of the hot stock as it moves through the mill, offers the possibility of finish rolling the stock without cooling for intermediate inspection and marking. This eliminates the expense of handling and reheating. The accurate control of depth of desurfacing reduces the volume of oxygen required, and the loss in steel removed. The quality of the surface produced by machine desurfacing will be reflected in a smoother finished product. With machine desurfacing, steel stocks such as high-carbon and alloy steels, which are difficult to spot scarf cold without surface checking, can be economically and effectively desurfaced with the oxy-acetylene process.

The choice between hand and machine deseaming depends on a variety of conditions among which are the quality of the product desired, the percentage areas of

FIGURE 12—View of desurfacing machine designed for edge scarfing of hot material.

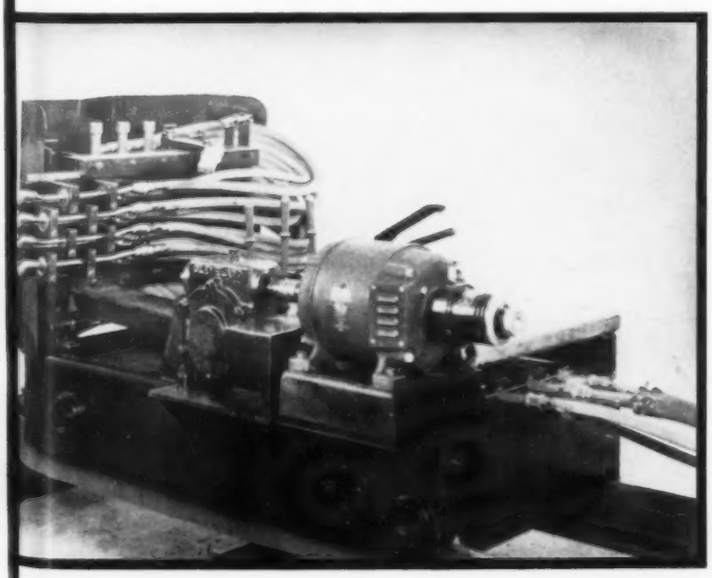
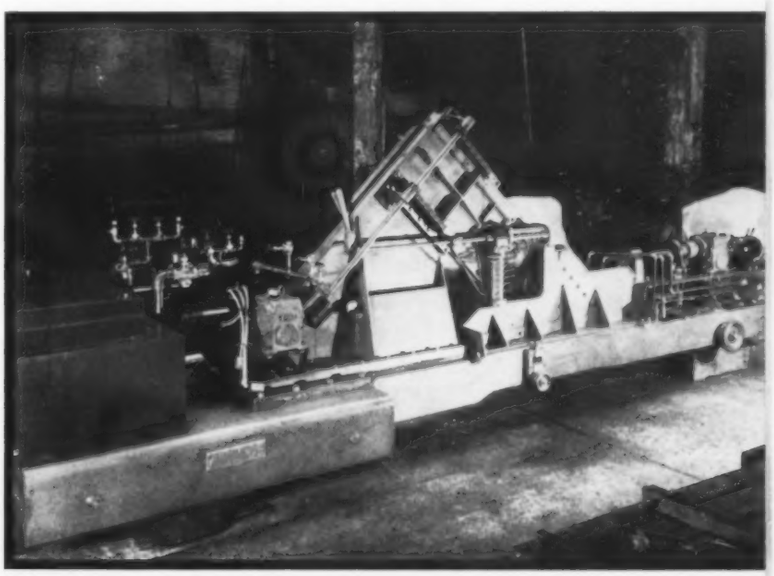


FIGURE 13—This stationary desurfacing machine is designed to remove all four surfaces of blooms on the mill table.



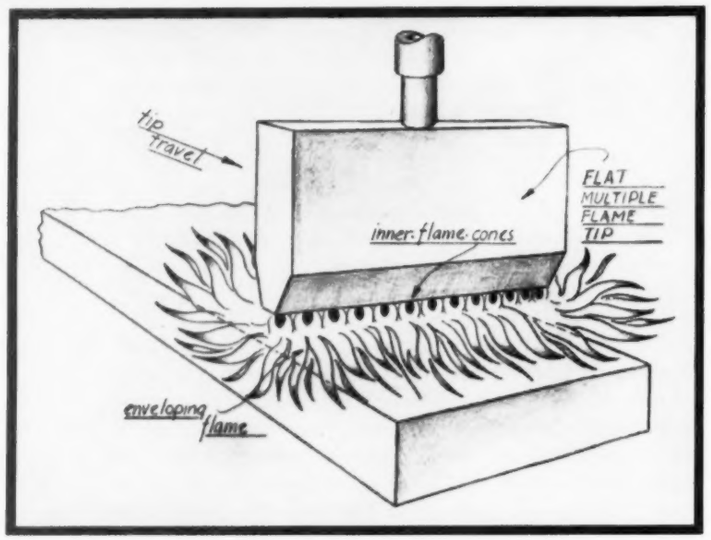


FIGURE 14—Flame descaling employs tips on extensions, so positioned that the enveloping flame completely covers the scaled surface for the expanse of tip flames.

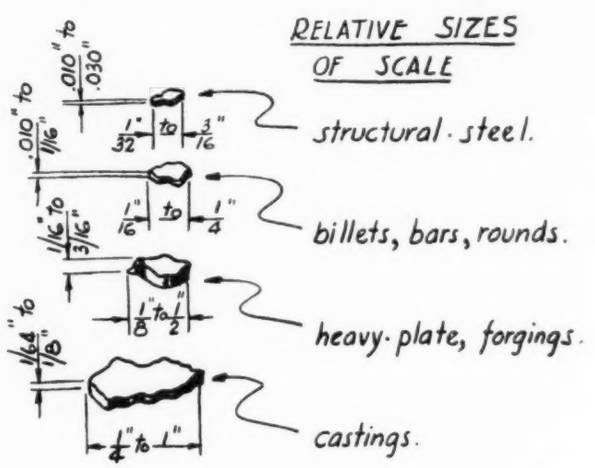
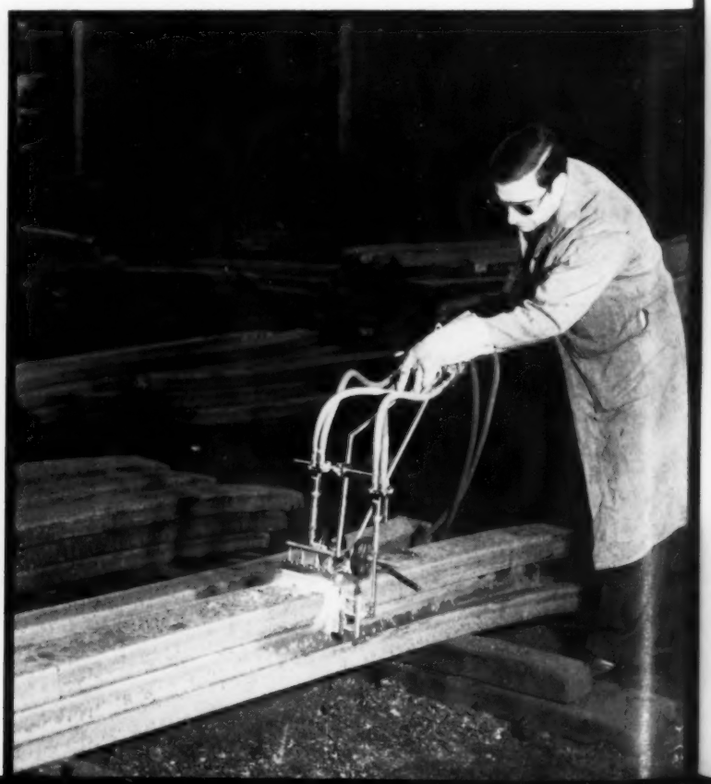


FIGURE 17—Flame descaling is accomplished by a differential expansion, causing scale to fly off in particles of various size, depending on the material descaled.

surface to be removed and the nature of the defects. On medium quality products, where intermediate cooling and stocking are necessary to fit the schedules of the finishing mills, hand torch deseaming is finding its widest application. Hand torch deseaming is also applicable where the surface defects consist of occasional deep breaks rather than large areas of shallow cracks, and where the stock can be torch conditioned cold. Machine desurfacing is indicated where large percentage areas of shallow defects must be removed to produce high quality products, where because of its analysis the material must be desurfaced hot, or where the stock must be conditioned at heat on the roller line.

FIGURE 16—Tips for descaling may be mounted on hard-faced skids, and traversed over the surface of the bloom.

FIGURE 15—In this design of flame descaling equipment the tips are mounted on a wheeled carriage.



MANUAL FLAME CLEANING OR DESCALING

Gradual recognition that thermal scaling of ferrous metals is a cause of manufacturing difficulties has resulted in rapidly spreading interest in means for the swift removal of surface accumulation of this kind. The presence of scale on steel billets prevents close inspection for the locating of minute defects and fine seams prior to flame scarfing or chipping. Pickling heretofore has been largely used to descale billets, slabs, rounds, barstock and frequently blooms and ingots.

Heavy and, frequently, hard scale on forgings and steel castings is damaging to cutting tools in the first machining cut and sometimes conceals defects that may later cause failure. Where such has been encountered pneumatic hammers or chisels or grinding facilities have been employed with a reasonable measure of success.

The flame descaling process employs the use of the oxyacetylene torch in combination with brush-type tips, on extensions (Figure 14), which are positioned so that the enveloping flame completely covers the scaled surface for the width or expanse of the tip flames. These tips are mounted on wheeled carriages as in Figure 15, or hard-faced skids as in Figure 16, and are traversed over the surface at the proper rate of speed to remove the maximum amount of scale. This speed will range from ten to twenty linear feet per minute. By means of the high temperature thus applied, the scale is rapidly heated without overheating the base metal. A differential expansion results, causing the scale to lift, crack and fly off in particles ranging from $\frac{1}{16}$ in. to $\frac{1}{4}$ in. in cross dimension on billets, bars, rounds and slabs and from $\frac{1}{8}$ in. to 1 in. cross dimension on forgings and steel castings. (Figure 17)

Flame descaling leaves a natural surface. Artificial resurfacing found in various other scale removing procedure is absent. A surface is disclosed, which to the untrained eye, is not recognized at first long range glance as being a clean surface. Close examination however will disclose that when the scale has been removed by flame descaling, the true unaltered surface of the metal is exposed. There is no chemical or physical action upon, or discoloring of, the base metal. The process is rapid and is one that can be fitted into a production line.

While the flame descaling process has not been developed to the stage providing for complete scale removal on all grades of higher alloy steels, it is found to serve satisfactorily for the greater volume of common grades of carbon and low alloys. In this service it reduces the tonnage passing through the pickle and thus the amount of pickle waste ultimately to be disposed of. The process may also be used to supplement the pickling operation in that the greater amount of loose scale may be flame descaled and the remaining lesser amount removed in a brief pickle with acid of reduced strength. The combination of flame descaling and light pickle of steels in plants where used has shown a reduction in pickling time of 50 to 75 per cent and a monetary saving of 15 to 25 per cent per ton cleaned, as compared with former methods.

DISCUSSION

PRESENTED BY

W. C. McCONNELL, *Plant Superintendent*, Republic Steel Corporation, Massillon, Ohio.

G. D. WINLACK, *Steel Mill Specialist*, Air Reduction Sales Company, New York, New York.

A. K. BLOUGH, *General Plant Metallurgist*, Republic Steel Corporation, Canton, Ohio.

H. G. R. BENNETT, *Engineer*, Hot Rolling Mills, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

J. M. REUBENDALE, *Chief Inspector*, Republic Steel Corporation, Youngstown, Ohio.

HAROLD M. FLAHERTY, *General Scarfing Foreman*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

W. W. JUSTICE, Industrial Engineering Department, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

J. J. DAVIS, *Chief Inspector*, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

A. H. ROOSMA, *Chief Industrial Engineer*, Republic Steel Corporation, Cleveland, Ohio.

H. E. PAETOW, Industrial Engineering Department, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

JOSEPH COOPER, *Assistant Chief Inspector*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

W. L. WITNEY, *Assistant Chief Industrial Engineer*, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

W. C. McCONNELL: I would like to ask one question on the scarfing angle. Comparing machine scarfing to hand scarfing, how does the tip life compare?

G. D. WINLACK: Tip wear will be practically the same. While there may appear to be a shorter overall life of the tips when comparing them to the life of tips in hand torches, the actual wear per lineal foot of material scarfed will vary very little. In other words, in a given amount of work the tip wear on machine scarfing shouldn't be any more than hand scarfing. Protection for the tips from heat of material is afforded by heavy collars or wearing rings.

W. C. McCONNELL: Of course, there is naturally the problem of the product that you get from scarfing. Are there any comments on the disposal of that product?

G. D. WINLACK: In most cases the product, or slag, is being used in blast furnaces, and in some cases in the open hearth and electric furnaces in place of mill scale.

A. K. BLOUGH: In regard to skin scarfing hot billets with a multiple head, what is the minimum depth removed? It is evident skin scarfing would result in a heavy metal loss.

G. D. WINLACK: I would say approximately $\frac{1}{16}$ in. is about as close as you can hold it now.

H. G. R. BENNETT: How high can we ordinarily go?

G. D. WINLACK: Practically any depth of surface can be removed from material when machine scarfing.

This is accomplished by setting of tip angles and speed of machine or materials going through machine.

J. M. REUBENDALE: There is one thing in connection with changing from hand-chipping to scarfing that should be brought out, and that is the fact that in the majority of cases there is an appearance that is very objectionable, which can be corrected through the proper training and education of men, and with the cooperation of the men on the rolling mills.

There is always a great amount of criticism of this fin and I think in many grades of steel that can be eliminated entirely. I think there is one place that the manufacturers of torch equipment have been sadly lax, in the fact that they haven't made enough effort to increase the efficiency of their torches and their equipment to eliminate definitely some of the objectionable features in scarfing. I believe most of that work, if they are honest about it, has been done through cooperation of the steel companies. This has been one of the greatest objections to scarfing, and until recent months very little progress has been made along that line.

There are some points in Mr. Winlack's paper on which I do not quite agree. One of them is the statement that you could get as much as 50 per cent saving. There are some cases where the costs of scarfing against hand chipping may be about equal, but I think there are other phases of the problem which must be considered in comparing the two processes.

Another thing that they sometimes overlook in scarfing is the comparison of their man-hour cost plus the metal removed, which, if you are going to be fair to either method, should be included with the actual man-hours per ton in any comparison.

G. D. WINLACK: As far as the criticisms are concerned they are justified for the past, but I don't feel that the case at present. Right now the oxygen companies are working along the lines that Mr. Reubendale suggests. For instance, on flash or fin removal, several different ideas are being and have been tried, but none have been successful enough as yet for practical use in the mills.

In regards to metal loss, this should be about equal with any cleaning method, providing that the proper equipment, procedure and setup is used. However, after all, it is the final cost per unit that counts. In scarfing operations labor savings generally more than offset any additional metal loss occurred.

W. C. MCCONNELL: This is not a matter of criticism, Mr. Winlack, but there is a statement in your paper that I will frankly say we do not find to be the case: "Facility to handle the torch is in most cases very readily acquired, and in a few days time the average man will produce satisfactory work."

I might say that it is requiring at least ten days to two weeks' time at the very earliest. I would like to have the opinion of others as to the time required for teaching a man how to handle the torch and become an average scarfer.

H. M. FLAHERTY: There is one question I would like to ask. Talking about 60 to 100 ft. per min., I would like to know what is the average speed?

G. D. WINLACK: That would be rather hard for me to answer, for the simple reason that I would have to know what type materials you are working and under what conditions. There are too many variables in the setups of the various plants to give a set average.

H. M. FLAHERTY: Is it possible to do 60 ft. per min.?

G. D. WINLACK: It depends entirely on the materials being worked. With proper equipment, procedure and operation, scarfing at this rate of speed is not uncommon.

H. M. FLAHFRTY: It has been a little bit different in our experience. We get up to about 30 ft. per min. and find that is as good as we can do.

G. D. WINLACK: Undoubtedly you are referring to torch speed per operator gross minute, while I am referring to the speed per torch net cutting minute. Assuming that 60 ft. per min. would be maximum, it would appear that if you are averaging 30 ft. per min. that your scarfers are only working at 40 to 50 per cent torch efficiency.

W. W. JUSTICE: I agree with Mr. Flaherty on the question of scarfing speeds. We have not been able to obtain speeds of over 40 ft. per min. in any of our plants in the Pittsburgh district. As a matter of fact we found that it was uneconomical to scarf at 40 ft. per min.

I would like to know what type of steel, what type of gases, and what type of conditioning are involved in your scarfing at over 50 ft. per min.

G. D. WINLACK: As I said before, the speed that I mentioned in my paper is based on a net cutting minute. Recently while installing scarfing operations in a plant, disbelief on the part of officials was voiced that the torch could even cut 50 lineal ft. per min. For visual proof we laid out a 2 in. x 4 in. x 20 ft. billet—.15–.17 per cent carbon, and cutting speed was 98 ft. per net cutting min.

J. J. DAVIS: Our scarfing experience at Youngstown has shown that on some grades and sections the actual savings in conditioning by scarfing hasn't been as much of a benefit as the time saving and number of men involved. I would like to ask on these grades that have to be re-heated to be scarfed, does the temperature used vary according to the grade of steel being conditioned?

G. D. WINLACK: Undoubtedly there are a number of people here who will disagree with me on this—but my experience for the past several years has shown me that it doesn't. The main thing after preheating the steel with low temperature is to get on with the scarfing at once and you will have no trouble with any grade of steel.

J. J. DAVIS: I would like to ask if anyone has had any experience with the auxiliary jet used in connection with the scarfing torch to remove the fin at the time of conditioning?

G. D. WINLACK: No, I can't tell you of anyone who is using it in actual production. We have had four or five of our own company's out in the field trying it.

While the jet does do the work, it hinders the man generally, due to the fact that he has to hold his torch in one position at all times. In production, the torch has to be flexible. At the present time we are working on the idea in the laboratory to have a "de-finning" jet on the tip, to allow the man to scarf in any position and still eliminate the fin.

(*Please turn to page 65*)

Safe CRANE Maintenance

By F. O. SCHNURE, *Electrical Superintendent,*
BETHLEHEM STEEL COMPANY
SPARROWS POINT, MD.

PRESENTED BEFORE THE NATIONAL SAFETY CONGRESS

▲ THE construction, operation and maintenance of cranes has been the topic of so many round table discussions that it is the concern of builders and operators alike, when buying new cranes, to see that nothing is overlooked in providing a well-designed dependable machine with a full complement of safety devices.

However, the average steel plant will contain some old timers whose complement of safety devices, in comparison with the modern crane, will bear about the same inverse relation as the bathing suit of its period bears to the 1940 model. Cranes of the early part of this century were devoid of anything but the bare essentials. The runways consisted of skeleton structures with either latticed braces for a walkway or none at all. Ladders without safety baskets led to the runways. Unfortunately, it is not always possible to completely modernize these old cranes, but when they have to be rebuilt or revamped, considerable can be done in the way of improvements.

The modern crane is a well-designed, compact mechanical, and electrical power plant, weighing from five to five hundred tons, supported overhead from girders designed with a liberal safety factor to take the crane and working load. Very few realize the variety and number of working parts that require attention; for instance, for the present day open hearth ladle crane, an approximate list would include 8 motors, 7 brakes, 24 wheels, 28 shafts, 44 sheaves, 16 sheave pins, 12 rocker pins and keys, 68 gears, 138 bearings, 6 magnetic controllers each made up of dozens of gadgets, 1000 or more bolts, 2500 ft. of cable and innumerable keys, gear covers, steps, ladders and appurtenances for oiling and greasing.

Both maintenance cost and safety depend upon the adequacy of the crane runways and cranes in strength, capacity, and number, to easily accomplish whatever is proposed, whether it be to operate an open hearth plant, unload ore, coal and scrap, handle the rolls and housings in a strip mill, carry plates and structural members in a shipyard, or ship 500 to 50,000 pound lots of product. When these units are not adequate, they are overloaded and strained; or, if not enough are provided, they are overworked and insufficient time is allowed for maintenance. In either case, excessive maintenance develops and the more exposure, the more chance for accident.

The second factor lies in the complement of safety walkways, stairs, platforms, and railings. Several years ago a new crane was placed in service with the idea that its walkway was adequately protected. A latticed outboard girder supported the bridge motor and line shafting and was solidly connected with the main girder by a six ft. wide corrugated plate walkway. It was not thought that any danger existed in the vertical openings of the outboard girder, yet a repairman, while in a stooping position handling a short piece of line shaft, stepped backward and "corkscrewed" through a 24 in. opening, until then not considered a hazard, falling to his death below. Walkways and railings should be so provided that the workman is as safe on a crane as in the shop.

Safe crane runways require ample clearances for a man between crane and building columns. This three ft. addition to the building width should not be considered too expensive for the protection it affords. The walkway should be kept clean, free from grease and should not be used as a storage for parts.

Modern practice has ruled that runways and cabs should be accessible by stairways wherever possible. This feature reduces the hazard involved in climbing even basketed ladders and eliminates infraction of the safety rule that repairmen shall not carry tools or parts in their hands while climbing ladders.

One of the most hazardous jobs is that of changing track wheels. To improve this situation, most large modern cranes provide a small platform under the girders, parallel to the end truck, which, although far from roomy and comfortable to work on, is safe and eliminates the necessity for a scaffold.

Repairs to sheaves usually require temporary rigging and scaffolds to support the repairmen. Any scaffold, because it is a temporary adjunct to a job, can be considered a hazard. It should be safely constructed, using lumber especially picked out and set aside for this work. Many plants make a practice of marking such lumber with a rigging symbol and not permitting any lumber but such so marked to be used in hanging scaffolds. Hand railings are a part of every scaffold. Accidents have occurred where supporting members have slipped from slings or have not been properly

nailed or fastened. The best of good judgment should enter into scaffold construction.

A crane should never fail as a unit. While hard usage, rust, and deterioration may eventually weaken the structure, inspection, coupled with good judgment, should correct or remove the hazard before the ultimate occurs. Failure of individual parts, however, does occur through wear and abuse. It follows then, that these parts should receive the best of engineering consideration.

Rails should be more than ample for the load imposed. They should be sufficiently hard to prevent working of the metal in the head and to maintain good joints and yet not hard enough to break under shocks that may be imposed by trolleys hitting the stops overly hard. More rails are changed because of bad joints than from wear; consequently, tapered heads with thermit welding of joints have come into practice. The latter presents the ideal condition of a jointless track, but because of the time involved in lifting the rail, welding and annealing cannot be as conveniently done as the former method.

Wheels, treated and untreated, tapered and plain, should be applied as the service dictates. The same thought applies to the gearing and when all factors are considered, it is difficult to justify anything but the best for hard worked cranes, and often that is not good enough.

A very high degree of development in electrical equipment such as motors, brakes, control, and limit switches, puts the onus of maintenance upon proper application. Manual controllers have no place on modern cranes, excepting those on very light duty. Controllers should be enclosed and be mounted accessibly on the girder wherever possible. Wiring should be done in such a manner as to forestall trouble. Controllers should be so arranged that they can be naturally and easily operated.

The link between the crane and its load can consist of any of a variety of forms of wire rope construction and reeving and is a most vital link in the safe operation of the crane. There is probably no part of the equipment that is more dependable than the cable and no part that receives less consideration and more abuse.

Conditions that tend to shorten cable life are: drums and sheaves of too small a diameter, reverse bends, over winding on drums, lack of lubrication, cable of wrong construction and of insufficient capacity for the service required, deeply worn grooves, broken rims or scored grooves by an old cable, sheaves that turn hard or wobble because of worn bearings, bent shafts, or anything that causes the pull on the rope to be uneven or jerky, and, more than anything else, the performance of work that should not be done by cranes, such as pulling of cars in spotting them under runways or the practice of making sidepulls that causes cable to rub against the edge of the girder.

Acceleration greatly increases the cable stress; consequently, care should be used in taking slack out of lifts and in the operation of the control board itself. The force of a hammer blow is impact; therefore, when even a light load being lowered is stopped suddenly, the cable is subjected to a stress much greater than power could apply to it in hoisting.

Broken wires, broken strands, and breaking of the entire cable may be caused by using a cable that is kinked or one that has been severely jerked. Vibration, whipping, and lashing are very destructive actions.

All of these points concerned with the wear, life, and selection of cable and the various crane parts enter into safe crane maintenance, because if there is no wear and infinite life, no maintenance would be required and the safety situation would not be a problem.

Codes and their interpretation vary from plant to plant, but basically are the same, being founded on the preservation of safety to all connected with crane operation. Crane operating rules are usually born after some casualty. The tendency is to make them too numerous and detailed to be comprehended by those who should be most conversant with them.

The following are submitted as a guide for crane repairmen:

1. When repairs are necessary, repairmen shall, if possible, have the crane run to a location where the repair work will least interfere with the other cranes and with operations on the floor.

2. Before starting repairs, repairmen shall see that all controllers are thrown to "off" position, and that main or emergency switches are opened; one of these shall be locked, tagged or tied open.

3. Repairmen shall immediately place warning signs or "Out of order" signs on a crane to be repaired and also on the floor beneath or hanging from the crane so that it can be easily seen from the floor. If other cranes are operated on the same runway, repairmen shall also place rail stops at a safe distance or make other safe provisions.

4. When working on crane runway or where the work being done on a crane prohibits crane from being moved until after job has been finished, rail stops must be placed on both sides of crane on both rails to isolate this section of runway or crane. If standard stop cannot be adjusted to rail a special stop must be obtained.

5. When it is necessary to work on a crane runway, in any location where it is not practicable to protect with rail stops, the foreman in charge of the work shall notify operators of all cranes using runway and responsible member of the repair gang shall also be placed in the crane cab with the operator to watch for the repairman.

6. Repairmen shall take care to prevent loose parts from falling or being thrown upon the floor beneath.

7. Repairs shall not be considered complete until all guards and safety devices have been put in place and the block and tackle and other loose material have been removed.

The best safety device is a careful man; consequently, all the safety rules and devices that can be applied, go for naught if the repairman is not constantly alert. Not many years ago, a fatal accident occurred in a plant where it was an established rule for every repairman responsible for a gang or certain class of work to apply a padlock to the switch of the crane under repairs. In this case, the crane was moved in the course of the job by another crane and with the knowledge of all concerned. The unfortunate man had misjudged the clearance between the roof truss and the trolley. Had the rule been followed to the letter; that is, all lockouts

removed before the crane was moved, the accident would presumably not have occurred, as all workmen should have been in cab or on walkway. This was a dual violation of a rule and of good judgment, for which there can be no substitute.

Safe maintenance depends upon careful inspection. When the crane can be taken out of service, the switches should be locked out, and signal lights displayed on temporary stops placed to protect this crane from others on the same runway. Part of this inspection should be done when the various operations can be observed in motion or while operating at regular work, in which case two men should constitute a crew, one stationed in the cab.

Ordinarily, this inspection is done by the regular repairman under the supervision of the foremen responsible for the maintenance of the cranes. It covers everything concerned with the operation of the crane from a preventive maintenance standpoint. However, in a plant where a large number of cranes are involved under a number of maintenance groups, it is often desirable to supplement the above with a crane inspector who periodically goes over each equipment in detail, making up a report which serves as a guide for the maintenance crew, as well as a record of the cranes' condition for future reference. This report should be kept on file.

Just as some drivers are harder on automobiles, some people harder on machinery than others, some crane operators are much harder on all parts of their crane than others. Frequently the operator who is the hardest on the crane from a mechanical standpoint is the most efficient from an economic viewpoint, because more than enough additional production is secured to offset the additional maintenance cost.

The crane cage is the cradle of many an employee in industry, who later and rightly so, moves on to more responsible jobs. It follows then, that since this is the proving ground, more than ordinary maintenance can be expected. If, by virtue of some circumstance, operators are retained on their job, it follows that their deftness and skill improve with consequent less and less wear and tear to the crane and its parts.

This was demonstrated several years ago when a dozen duplicate cranes were transferred from an old plant to another. Half of them were placed in service on an operation that had also been transferred—machinery and men, including crane operators—all settled, seasoned men. The other six cranes were installed on similar service, but were, and are, being manned by younger, less experienced operators. The maintenance on the former, with old control equipment, is considerably less than the latter installation where modern control had to be added to protect the cranes.

All of which again shows the crane operator to be an important link in the operations of the crane and its maintenance. All men are not equal in practical ability and mental capacity and crane operators are no exception to that rule. The better the talent that can be placed in this job, the better the results.

The old saying—a stitch in time saves nine—is just as true in crane maintenance as in any other line. However, the crane is a unit in a line of production and often can not be spared at the time inspection recommends.

DISCUSSION

Details of Design

NO. 5 BLAST FURNACE, INLAND STEEL CO.

(Continued from page 42)

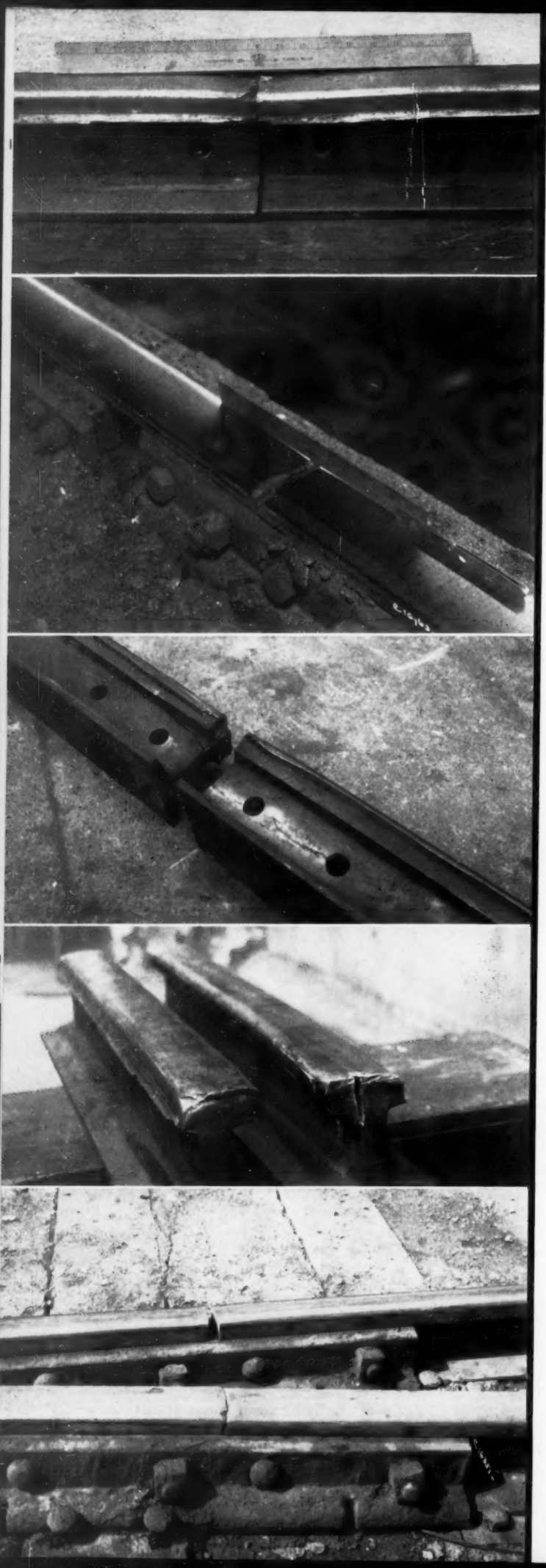
the present state of knowledge it is best to measure results by carbon consumed per ton of iron, and not by surveys.

CONSTRUCTION

The importance of the amount of drop from the dumping point of the skip to the bottom of the large bell should not be exaggerated. This distance is 26 ft. on No. 5 furnace. However, data presented shows the beneficial effect of removing fines from the coke charged into a blast furnace. Consequently, if we are justified in screening the coke just before it goes into the skip then we certainly should make every effort to avoid producing more fines on the subsequent handling into the furnace.

Of the total drop from skip to bell, a large part is from the small bell to the large bell. The deeper the large bell hopper, as sometimes provided for the large charges, the greater the drop. Since the paper was presented, the filling on the furnace has been changed so that less of the space provided between the bells is used, and there has been improvement in operation on the new filling. If we had known this when designing the furnace and made the hopper 2 ft. shorter we would have had less coke breakage, and it would be logical to expect that results would have been better.

The effective height of a blast furnace is to the top of the stock column, not to the dome ring. Any additional height of hopper not actually required merely increases the total construction cost of the furnace.



WELDING

and Joints

FIGURES 1 to 5 *(left)* illustrate various types of rail defects, respectively, from top to bottom: low rail joint, battered rail ends, web cracks through bolt hole, split rail head, and rolled out surface, which is the start of a battered rail end.

▲ THE application of welding to steel rails is not a new development as in some of its different forms, the art of welding has been in use by the railroads and street railways for several years. It has been successfully adopted for building up low joints, renewing worn switch points and more recently for the production of continuous lengths in main line trackage by welding the rail ends solidly together.

In view of its successful history in railway service, there seems to be no inherent metallurgical reason why welding should not be applied with equally beneficial results to overhead crane runway rails provided its use is found to be economical and provided the presence of a rigid supporting structure instead of a resilient road bed and the absence of curves or grades in which expansion strains could be absorbed, do not introduce serious difficulties. The object of this paper is to present some details of the experience gained during the past year in welding crane runway rails both for building up low and battered ends and in the production of semi-continuous and continuous welded lengths. While the operating experience is still too short to justify final conclusions, it is hoped that the information here presented will be of some assistance to others who may be considering welding as a solution of an important steel mill maintenance problem.

Crane runway rails when installed with splice bars and subjected to reasonably heavy duty service, frequently develop joint defects of such character as to affect crane operation and to require either excessive repair expense or entire replacement before wearing depth of the rail head is exhausted. These defects manifest themselves principally as low and battered rail ends, web cracks through the bolt holes, split heads or shear cracks between web and tread. Visual examples

# of RAIL ENDS of Crane Runways

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McKEESPORT, PENNA.

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TABLE I

Wheel Loads for Overhead Cranes

DUTY	Wheel Diameter In.	Normal Speed Ft. per Min.	Max. Wheel Load Lb.
200 ton ingot pouring crane	30	250	100,000
10 ton soaking pit crane..	26 5/16	274	80,000
10 ton billet storage crane	24	350	50,000
10 ton shipping crane....	24	350	35,000
Freight gondola car (50 mi. per hr.).....	33	4400	26,200
Yard locomotive (10 mi. per hr.).....	52	880	28,000
Main line freight locomotive	58	4400	33,800
Roll pressure per inch of width breakdown stands cold mills.....	24" roll	800	73,000

of these various defects may be observed in Figures 1, 2, 3 and 4, while the start of a so-called battered rail end is disclosed in Figure 5.

It seems quite probable that these defects find their principal origin in the heavy rolling loads imposed by the track wheels on the rail head combined with the inherent weakness of the non-continuous rail with its abrupt termination of resistance to metal flow at each end, and to the reduced web sections at the bolt holes. An example of the longitudinal displacement of rail head metal may be seen at the end of the rear rail in Figure 5, while Figures 1 and 2 show how the displaced metal has broken off due to the relative vertical movement of the abutting rails and which will ultimately result in what is commonly called a battered rail end.

As a matter of interest, there is included at this point (Table I) a brief tabulation of characteristic maximum wheel loads to which crane runway rails may be subjected in comparison with standard railway wheel loads, and also the roll pressure per inch width of strip currently used in modern cold strip mills.

From the pressures indicated in this tabulation, it seems that purchasers of cranes might well consider means of reducing wheel loads in order to increase the life of crane runway rails.

While the building up of battered rail ends by weld deposits of hard surfacing electrodes has been practiced successfully for several years by numerous railroads, the commercial companies engaged in this service apparently have been deterred from applying their art to crane runway rails possibly because of the difficulty in quoting an attractive price for a job which usually is hampered to considerable extent by mill operations and other working conditions. However, the mill maintenance forces can usually take advantage of any lull in operation and therefore will find opportunity to apply this same method of repair welding to low joints or battered ends on the crane rails provided properly qualified men and the necessary facilities are available.

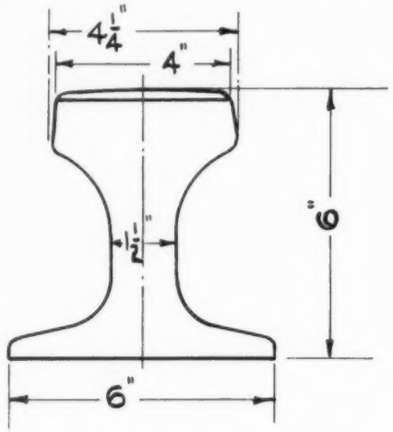
In order to determine the durability and economy of welding on rails supported by a rigid runway girder, a trial installation was made on a section of runway containing forty-three joints which had developed low and battered ends to such an extent that it had become necessary either to replace the rails or repair the joints. The defects were located in a heavy duty area of a 200-ton ladle crane runway which was fitted with 175-lb. rails having the following characteristic analysis:

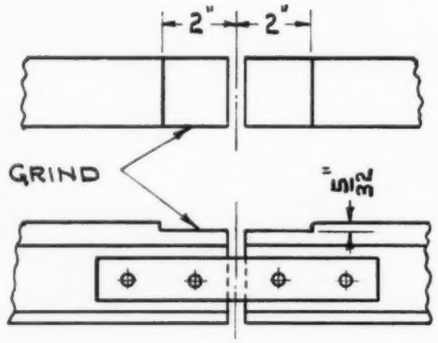
C.....	.73 per cent
Mn.....	.40 per cent
Sul.....	.023 per cent
Phos.....	.030 per cent
No alloys	

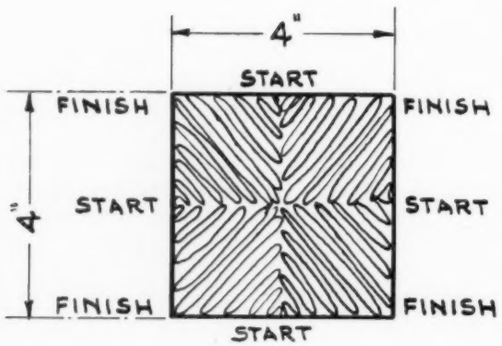
Repairs were made by building up the low or battered joints, using the metallic arc, oxy-acetylene and atomic-hydrogen weld processes with and without preheat and with several different electrodes listed by the manufacturers for this class of material and service. The physical preparation of the rail ends prior to welding and the procedure followed for each process are shown in Figures 6 and 7, while appearance of a typical finished joint after a short period of service is shown in Figure 8.

A somewhat different method of repair welding was then applied to a group of thirteen defective joints in the same 175-lb. rail section. In this method the heads of the rail were butt welded solidly together, leaving web and base unwelded and reinforcing the joint with a "J" weld at the upper edge of the splice bar and a fillet weld at its lower edge, thereby producing what might be termed a semi-continuous weld and eliminating the previously existing defective ends entirely. The metallic arc was used for these welds. The physical preparation of this joint and the welding procedure followed are

shown in Figure 9, while its finished appearance is shown in Figure 10.







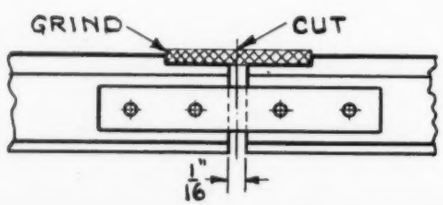


FIGURE 7

Procedure for Building-Up Battered Rail Ends—175 Lb. Rails

Atomic-Hydrogen Process

Oxy-Acetylene Process

1. Grind rail ends approximately $\frac{5}{32}$ in. deep, removing all battered or splintered parts, oil, grease and dirt.
2. Use $\frac{3}{16}$ in. diameter x 36 in. long filler rod (rail surfacing rod).
3. Preheat to 500 degrees F.
4. Preheat flame to be applied only to ground surface.
5. Apply metal as shown in sketch, puddling into parent metal beginning at splice.
6. Peen each bead while hot.
7. Deposit to be sufficient to provide good, clean surface after grinding.
8. (Oxy-acetylene process only.) Oxy-acetylene to be adjusted for slightly reducing flame.
9. Weld to be ground clean and square; cut at splice to depth of weld with $\frac{1}{16}$ in. abrasive wheel.

In a third trial installation on four joints, in the same heavy duty runway, the rails were welded into a continuous length and splice bars omitted entirely. The thermit process was used for two of the joints and the metallic arc and oxy-acetylene fusion process were used in each of the remaining two. Following the satisfactory preliminary results from these trial welds, thirteen 33 ft. 105-lb. rails located in the heavy duty side of a three-crane soaking pit runway were then welded into a continuous length and the same procedure was followed with twenty-eight 39 ft. 105-lb. rails located in each side of a two-crane pipe processing runway. The metallic arc process was used for each of the full length installations, principally because of its simplicity and relative ease of handling.

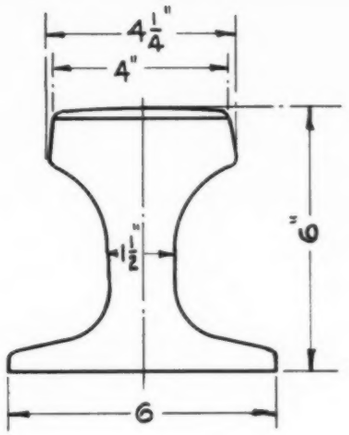
The physical preparation of the rail ends for the solid welds and the procedure followed for each of the three processes are shown in Figures 11 and 12, while Figures 13, 14, 15, 16 and 17, illustrate the various steps followed in making the complete metallic arc weld. In making the continuous welded rail, it was found advisable for reasons of economy and convenience to line up three or four lengths on the floor, weld, stress relieve, and grind in that position and then hoist the joined lengths to the crane runway where the remaining welds were completed. This plan reduces the out-of-service elapsed time and restricts scaffolding to a mini-

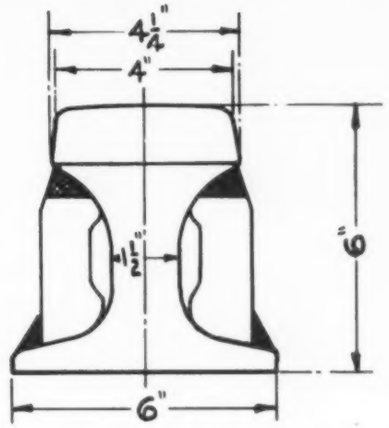
FIGURE 6

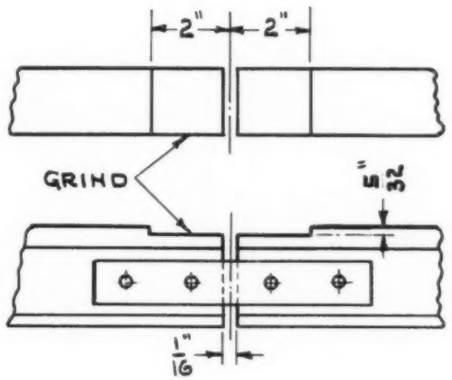
Procedure for Building-Up Battered Rail Ends—175 Lb. Rails

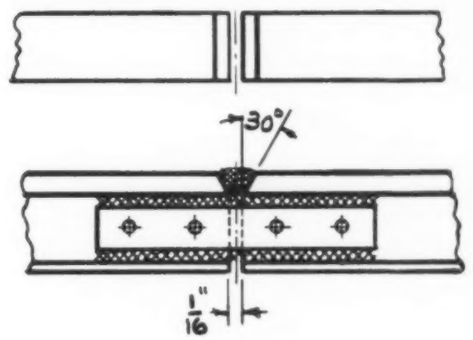
Metallic Arc Process

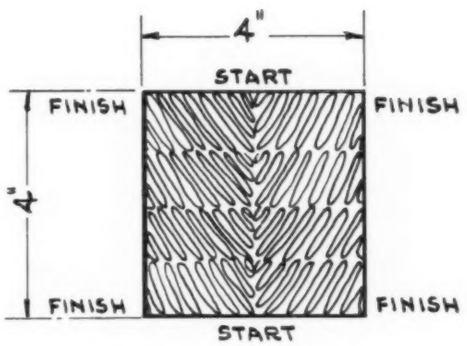
1. Grind rail ends approximately $\frac{5}{32}$ in. deep, removing all battered or splintered parts, oil, grease and dirt.
2. Divide rail end to be welded into sections 2 in. square.
3. Preheat to 500 degrees F. where used.
4. Use $\frac{3}{16}$ in. diameter, heavy coated, hard surfacing electrodes.
5. Weld as shown in sketch—complete the first square section to its full height; then the second square section in the same rail; then the first square section in the other rail; then the second square section.
6. Peen while hot; wire brush thoroughly.
7. Deposit to be sufficient to provide good, clean surface after grinding.
8. Welds to be ground clean and square; cut at splice to depth of weld with $\frac{1}{16}$ in. abrasive wheel.











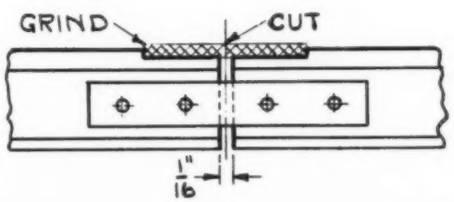


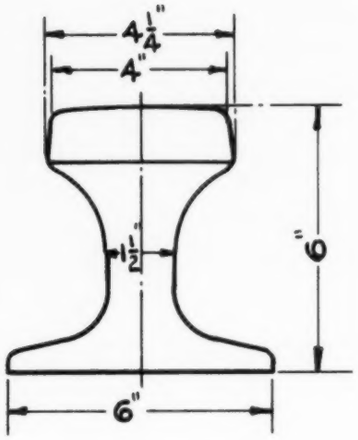
FIGURE 9

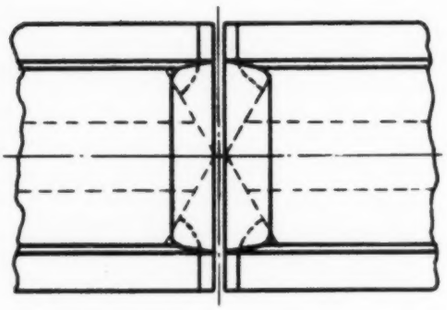
Procedure for Welding Semi-Continuous Joints—175 Lb. Rails

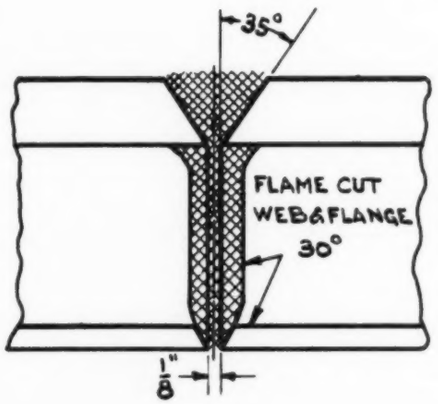
Metallic Arc Process

1. Splice bars removed, prepared as sketched with oxy-acetylene cutting torch. Cut ball of rail with oxy-acetylene torch as sketched, scale to be removed with hand hammer and chisel.
2. Preheat ball of rail to approximately 1200 degrees F.; weld to within $\frac{1}{8}$ in. of flush with $\frac{3}{16}$ in. diameter heavy coated, mild steel electrode (140–240 amperes) beads deposited in single layers at right angle to length of rail, remove slag, and wire brush thoroughly after each deposit.
3. Ball of rail to be finished with three layers of $\frac{3}{16}$ in. diameter heavy coated, hard surfacing electrode, weaving beads laid diagonally to length of rail, deposit overlapping by one-half, sufficient to permit clean, ground surface.
4. Preheat splice bars to 1200 degrees F., weld with $\frac{3}{16}$ in. diameter heavy coated, mild steel electrode. Single "J" type butt weld being formed between splice bar and heaviest section of web, directly under ball of rail. Approximately $\frac{7}{8}$ in. fillet weld formed between foot of splice bar and base of rail.
5. Entire weld reheated to 1600 degrees F., covered with crushed magnesia pipe covering for slow cooling.
6. Grind weld true and square with surface of rail head.

FIGURE 8—View showing appearance of typical finished built-up joint after a short period of service.







mum. While the period of service from the continuous rails is still too short to reach definite conclusions concerning the ultimate life of the joints, the preliminary results are very encouraging. The unbroken rolling surface results in very smooth crane operation which should be reflected in lower maintenance costs both for the cranes and crane runway girders. The relative durability of the three different welds is yet to be established, as at the date of this report there is no visible evidence of any greater damage to the welds than exists on the surface of the rail itself.

The first group of four solid welded joints have now been exposed to the effects of a complete range of winter and summer temperatures without developing any expansion difficulties. In the remaining installations in which the rail is continuous for practically the full length of the runway, the temperature range has so far been limited to the spring and summer variations. Creep

FIGURE 10—View of finished semi-continuous welded joint reinforced with splice bar welds.

measurements taken from time to time have so far failed to disclose any material changes.

Each weld has been inspected periodically since installation, and its condition under service has been graded as "A-1," "Good," "Fair," or "Poor," in accordance with the visible evidence of any deterioration which can

FIGURE 11

Procedure for Continuous Welding of Rail Joints—175 Lb. Rails

Metallic Arc Process
Oxy-Acetylene Process

1. Flame cut rail ends as sketched; scale removed with hand hammer and chisel.
2. Line up rail ends, spacing to be $\frac{1}{8}$ in. between abutting ends.
3. Preheat with oxy-acetylene torch to approximately 1200 degrees F., 4 in. each side of joint.
4. Two operators working simultaneously at opposite sides of rail, begin welding at outside edge of flange to web, continuing vertically up web to head of rail. Reinforcing of flange and web to be $\frac{5}{32}$ in. plus.
5. Reheat to approximately 1600 degrees F., with oxy-acetylene torch 6 in. each side of weld, cover with crushed magnesia pipe covering for slow cooling.
6. Grind weld true and square with surface of rail head.

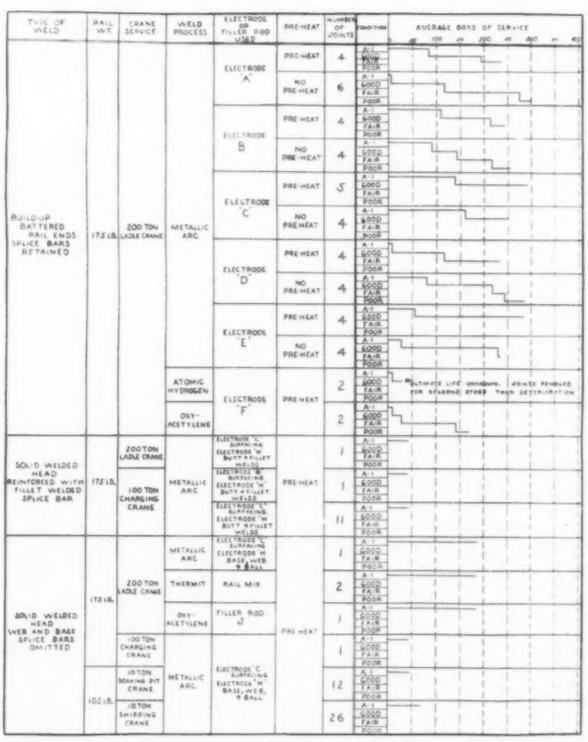
Metallic Arc Process (Only)

7. Web and flange to be welded with $\frac{3}{16}$ in. diameter heavy coated, mild steel electrode. Reinforce approximately $\frac{5}{32}$ in.
8. Head of rail to be welded to within $\frac{1}{8}$ in. of flush, with $\frac{3}{16}$ in. diameter heavy coated, mild steel electrode. Beads deposited in single layers at right angle to length of rail by one operator; slag removed and deposit wire brushed by other welder.
9. Head of rail to be finished with three layers of hard surfacing, $\frac{3}{16}$ in. diameter heavy coated electrode. Deposit sufficient to permit ground surface clean and square.
10. Weaving bead laid diagonally to length of rail, deposit overlapping by one-half.

Oxy-Acetylene Process (Only)

11. Head of rail to be welded by operators alternating between depositing metal and applying torch to keep temperature constant.
12. Use $\frac{1}{4}$ in. diameter (special rail rod) filler rod, No. 9 welding tip, slightly carbonizing flame (excess acetylene).
13. Deposit on head of rail to be sufficient to permit ground surface clean and square.

TABLE II



be observed. This method of inspection and rating has been useful in establishing the relative merit of the different electrodes and procedures used in building up battered rail ends, and ultimately will permit a reasonably accurate evaluation of the three processes used in making the semi-continuous and continuous welds.

In Table II an attempt is made to present graphically, and in a condensed form, a summary of the various welds and procedures followed, together with the service results to date from each, as disclosed by the inspections. These results will be found in the series of small graphs in the right hand columns of Table II. In examining these results it should be understood that all the trial welds, with two exceptions, are still in service. The two atomic-hydrogen built-up joints exhibited considerable wear, soon after going into service, and were removed before their useful life was exhausted and unfortunately their ultimate serviceability will not be established in this trial investigation. Two of the metallic arc joints also developed early defects and were replaced in kind. It is entirely possible that each of these failures was due more to faulty technique of the welder at the start of the job than to any inherent weakness in the process or electrode used. The built-up welds which remain longest in the three highest ratings will indicate the relative superiority of the electrode and procedure used for the service conditions encountered, while those which first deteriorate to the rating of "Poor," thereby indicating the necessity for repairs, will be discarded.

At wage rates now prevailing in steel mills of the Pittsburgh district, the average cost of labor and materials required in building up a group of low and battered ends of the 175-lb. rail section was found to be approximately $9.78 per joint for the metallic arc process using preheat, $11.54 for the oxy-acetylene, and $13.54 for atomic-hydrogen. Under the same wage scale a new 175-lb. section rail with splice bar joints, erected in position is estimated to cost $90.40 per 39 ft. length. Prior to date of repairs, the old rails had given approximately seventy-four months of reasonably active service. Therefore, it will be seen that the cost of built-up repairs will be economically justified when the useful life of the old rails has been extended an additional eight to ten months. From the life records shown in Table II, it is evident that the group of built-up joints which were metallic arc welded with preheat and using electrodes *C* and *E* will meet this requirement with a satisfactory margin to spare. These welds have now been in service approximately ten months, during which time they have required no repairs, although several others which were welded without preheat and with different electrodes will soon require repairs.

The direct welding cost for the semi-continuous, reinforced splice bar joint was found to be $26.91 per joint for the metallic arc process. These welds have now been in service approximately three months, are still in "A-1" condition and with no visible evidence of failure. Under the initial cost and service life previously outlined, these semi-continuous rails must continue to render useful service for a total of twenty-two months before their cost will be economically justified. The outcome cannot be predicted at this time.

In considering the cost of solid welded joints, it will probably be most useful to those who may be interested

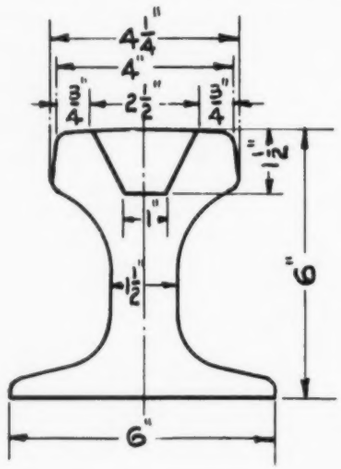
FIGURES 13 to 17 *(right, top to bottom)* show steps in making the complete metallic arc weld: rails blocked and aligned, ends beveled and jigged, slow cooling after reheating, joint as welded, and joint after surface grinding.

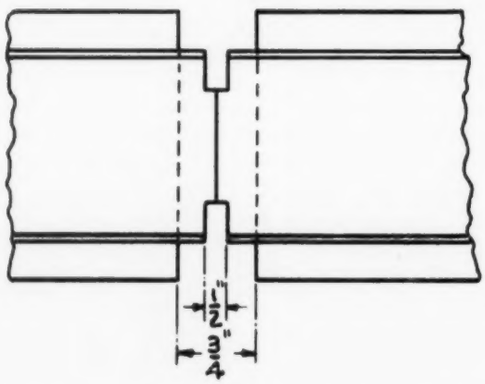
FIGURE 12

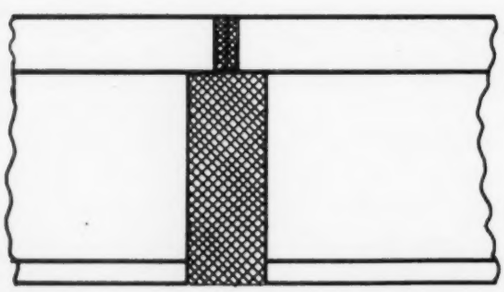
Procedure for Thermit Welding of Rail Joints

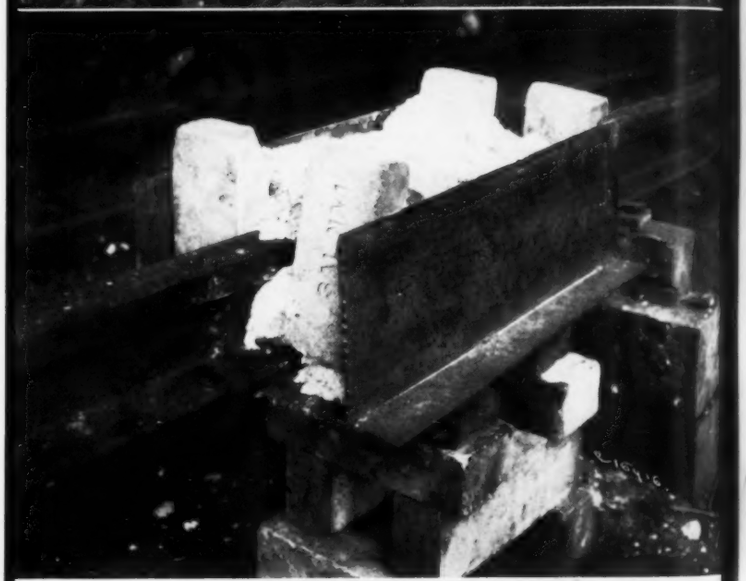
175 Lb. Rails

1. Rail ends prepared as per sketch by oxy-acetylene cutting torch; scale to be removed; ball of rail where joint butts to be ground clean and square.
2. Rail ends lined up to allow $\frac{1}{16}$ in. rise for one ft. each side of butt, determined by two ft. straight edge, clamping device drawn tight.
3. Moulds placed and clamped in position.
4. Joint preheated to 1600 degrees F., mould inspected; and loose material blown out if any.
5. Vent hole plugged with steel rod and cemented with moulding material.
6. Joint brought up to 1800 degrees F., heating gate closed with metal cap and cemented with moulding material.
7. Thermit reaction (special rail mix) immediately tapped from crucible
8. After approximately ten minutes, remove moulds.
9. Cut off riser sections and reinforcement along edge of rail head.
10. Grind weld true and square with surface of rail head.









to compare the cost per foot of rail length erected in position on the runway girder with like figures for a non-continuous rail installed with standard four bolt splice bar joints. In the basis of the cost figures so far accumulated, the relative values are set forth in Table III, and from them the economic value of the solid welded joint may be estimated.

TABLE III

Direct Cost per Lineal Foot of 175-lb. Rail and Joints Erected in Position Ready for Service

Rail Length	Splice Bar		Thermit		Metallic Arc		Oxy-Acetylene	
	Cost per Foot	%	Cost per Foot	%	Cost per Foot	%	Cost per Foot	%
39′	$2.32	100	$2.69	116	$2.57	110	$2.66	114

It should be understood that these cost figures may vary considerably in a given installation due to working conditions, skill of personnel, wage rates, equipment and facilities available, etc. The percentage indicates, however, the approximate increased rail life which must be secured from a continuous welded rail in order to justify its cost. Based on present indications and reports from other installations, there is every reason to expect a liberal return on the increased investment in the solid welded rail for those installations where replacements now occur because defective splice bar joints develop before the rail head has exhausted its final ten to fifteen per cent of wearing depth.

No attempt will be made at this time to credit the continuous welded rail with any savings which may reasonably be expected in decreased maintenance expense on cranes and runway girders, due to the elimination of shock loads which exist in greater or less severity as bolted joints gradually deteriorate. It will require several years' operation to permit any worth while estimate of the value of this factor.

From the experience thus far gained, the following conclusions appear to be justified:

(1) Defective joints in existing crane rails may be successfully and economically repaired by welding, provided—
   (a) The defects are limited to low and battered ends.
   (b) Proper welding procedure and suitable welding electrodes are used with costs restricted to reasonable values.
   (c) A year or more of useful life remains in wearing depth of the rail head.

(2) The welding of crane rails into continuous lengths will be found economical in those installations where deterioration of splice bar joints under service conditions has been found to force replacement when ten to fifteen per cent of useful life remains in rail head.

Winlack DISCUSSION

(*Continued from page 54*)

A. H. ROOSMA: Nothing has been said about the kind of fuel used for scarfing. As a matter of information, I would like to hear some discussion as to what type of fuel is the best fuel to use, or whether one type is more economical than another.

H. M. FLAHERTY: I have used hydrogen, butane, natural gas, and a few more; I couldn't see any difference between the speed with the various gases. After you once get your cut started, your oxygen, of course, does all the work. It seems to me that the natural gas gives you a cleaner and brighter cut. I have been able to operate a torch around 50 or 60 ft. per min. with higher pressures of oxygen, but I have never been able to make a good cut at that pressure.

In the forging quality steel, if you cut and make fins you are liable to get into trouble. That is what we have always found when operating torches at a high rate of speed.

The oxygen pressure, it seems to me, has a lot to do with the type of cuts you make. If you don't clean the whole surface of the bloom, especially on bad steel, where you have to skin the whole surface, invariably, wide cuts will leave fins which will not scale off in reheating.

If a fellow comes in, and tries to make a cut, taking a 5 in. bloom, it is possible that he can scarf that 5 in. bloom in four cuts, but he doesn't remove all the surface defects. When we skin a bloom we make a cut about an inch and a quarter wide; and if it is a skin job we lap that cut over about a half inch to clean up all fin. It seems to me from tests now being conducted that with acetylene gas a similar procedure should be followed if we want to make a good skinning job.

H. E. PAETOW: For best efficiency, what is the best position for the billet relative to the scarfing torch, flat or tilted?

G. D. WINLACK: I would say if you are doing bench scarfing, keep it flat. If you are doing ground scarfing, tilt it. It appears that the operation is being slowed up by tilting the steel, but you more than offset this small loss of time through benefits of faster scarfer operation.

JOSEPH COOPER: I would like an answer to the question as to how long it takes to properly train a man for scarfing.

J. J. DAVIS: Our experience indicates that, on an average, from a month to six weeks is necessary, depending upon the man himself. We have tried some men for three months and then found it necessary to place them in other positions.

H. M. FLAHERTY: Some men take two weeks, some ten days, and some about a week. We find, however, that we don't get a very good man until he is there about three or four months.

W. L. WITNEY: I believe it would take approximately six weeks to break in a scarfer.

"Here's how

WE SPIKED NEEDLESS SHUTDOWNS FOR SOUTHERN CALIFORNIA FISH CO.

with BUSS FUSES"

says R. J. Gatlin, Manager of Gatlin & Co., Electrical Contractors of Wilmington, Cal. "We were getting repeated calls from Southern California Fish Co. to replace the fuses in the main power switch. The fuses were 600 amp. 250 volt size and were blowing out on an average of once a month.

"We checked switch and motors and the entire circuits but could not prevent the fuses from heating excessively and blowing needlessly.

"Finally we decided to see if there was anything to the claim that BUSS Super-Lag Fuses would eliminate needless blows.

"On May 27th, 1935 we removed the old fuses and replaced them with BUSS Super-Lag Fuses. To date not a single needless blow has occurred."

BUSS Super Lag

DON'T LET OTHERS GET THE JUMP ON YOU WHEN IT COMES TO MONEY SAVING IDEAS

If needless blows are causing shutdowns in your plant, why not be the first to recognize the service BUSS Super-Lag fuses can render you?

Needless blows caused by poor contact heating have practically been eliminated in BUSS Super-Lag fuses by a Fuse-Case design worked out through years of laboratory and actual field tests.

... and BUSS Super-Lag fuses have a time-lag feature that really does go a long way towards solving the shutdown problem when the shutdowns are being caused by fuses blowing on temporary or momentary overcurrents.

That's why users of BUSS fuses enjoy a freedom from costly interruptions of electrical service that formerly were so often a burden upon the shoulders of the executives in charge of production or maintenance.

How to get action

Just knowing about BUSS Super-Lag fuses doesn't save any money—unless the fuses are in your fuse clips. So why not get action that means money saving by passing the word along that from now on all fuses installed are to be BUSS Super-Lag fuses?

Your electrical wholesaler has or will get BUSS fuses for you ... Bussmann Mfg. Co., University & Jefferson, St. Louis. Division of McGraw Electric Co.

FUSES

CARBON LININGS *for Blast Furnaces*

By F. J. VOSBURGH

Manager, New Products Division

NATIONAL CARBON COMPANY, INC.

NEW YORK, NEW YORK

▲ THERE is a surprising lack of information about the use of carbon bricks and blocks as blast furnace lining materials in our technical literature, and even abroad where the application is more general, little data is available. The earliest report of the use of carbon as a blast furnace lining material appears to be that of Burgers in 1890 in *Stahl und Eisen*, though he refers to an earlier statement by A. Purcel in 1885 disclosing the use of "blocks of graphite" made from retort carbon and tar, and baked, which had been used as hearth and bottom blocks in a ferro-manganese furnace. An earlier record indicated that Henderson of Glasgow had used coke blocks, probably foundry coke and tar, mixed, formed, and baked, as a hearth in a reverberatory ferro-manganese furnace in the early sixties.

Naturally many blast furnace operators experimented with the new material, but it was not until 1912 that anything was published regarding this development. As might be expected, all sorts of reports were made, good, bad and indifferent. The operators had tried hearths from 10 in. thick up; some had used bricks corresponding in size to the usual ceramics; while others had tried sizable blocks. Some had water-cooled in the usual way by spraying on the water, while others had used no cooling.

In general, it was recognized that carbon and ceramic materials had little in common except perhaps shape, and that a different technique was necessary for carbon than for ceramics. It was evident that the usual blast furnace was not designed for carbon linings, for it was not of air-tight construction, a primary requirement if carbon were to be used, and of no particular importance with ceramic linings. At that time most of the furnaces used bands and not complete shells about the hearth portion. The operators found out too, that carbon blocks could not be used around the tap hole. They discovered that combining carbon and ceramic materials did not work well.

Regardless of the difficulties encountered, it was clear that carbon materials had some distinct advantages. If oxidation could be prevented, carbon lasted remarkably well, for it was attacked by neither the metal nor the slag. If the blocks were well made, little shrinkage took place because of the operating temperatures. That carbon did not soften, or lose strength while in use, and that it had a low coefficient of expansion, were good characteristics.

It is peculiar that certain districts were more successful than others in their use of carbon and therefore went ahead in using it, while others held back for years. Still, progress was made and today seventy-five per cent of all German blast furnaces are reported to be carbon lined. Perhaps varying conditions accounted for some operators taking to carbon while others refused to accept it. Differing ores may have had some effect, and variations in ceramics may have had an influence. It is generally recognized that German clays are relatively poor as compared with those found in the United States, and no flint clays are available at all.

Carbon materials thirty years ago, even when made by the best manufacturers, were not comparable with similar articles today, electrodes, for example, or brushes, or lighting carbons, and undoubtedly the carbon brick of that period would not compare in quality with those manufactured today.

Of course ceramic manufacturers were much concerned by the interest in the new material which might take away their business, and as a result, many of them began to manufacture carbon brick since they had the equipment for most of the operations. It is questionable whether their knowledge of ceramic manufacture was of great value in view of their lack of knowledge of carbon, but at least they were able to produce brick in sizes corresponding to their ceramics. Some of the blast furnace operators saw no great difficulties to be encountered in making carbon brick, and so attempted it themselves. The general results were not good. The bricks were low in density and not particularly resistant to heat shock. They were made in the same sizes as the ceramics, so did not reduce the number of joints and the chances of penetration and run-outs.

The carbon manufacturers were not much better off, for though they knew a lot about carbon and had the requisite knowledge for forming it properly and thoroughly baking it, still they were to a greater or less extent limited in their manufacturing by restrictions set

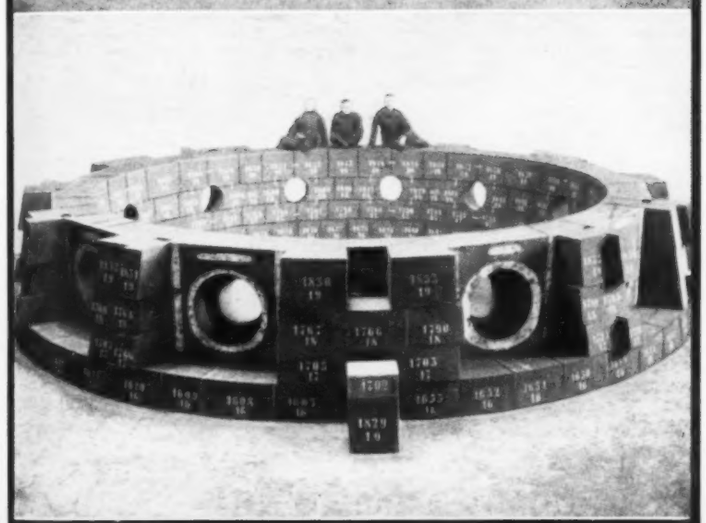


FIGURE 1—Rectangular base blocks and first layers of radial blocks for hearth of carbon lined blast furnace *(top)*.

FIGURE 2—View showing carbon block construction used for the tuyere zone of a carbon lined furnace *(middle)*.

FIGURE 3—Sectionalized view of a carbon hearth and crucible using large base blocks and smaller blocks above *(bottom)*.

up by the blast furnace operators—restrictions based on their years of experience using ceramic materials in furnaces primarily designed to use such materials regardless of their inherent weaknesses.

In spite of all those factors, carbon linings became more generally adopted, and, as furnace designs were changed to give carbon a better chance to perform, its use was extended to take in all of the furnace lining up to the mantel. The carbon manufacturers were able to readily make larger blocks than the brick manufacturers, and, since the advantages of the large blocks were obvious, many blast furnace operators turned to them.

As a result, developments ran to linings of two types in so far as size of pieces were concerned, the one using standard brick sizes and the other using blocks from large brick size on up to pieces weighing 3,000 lb. or more, with the large blocks having the advantage. As more furnaces were lined, it became evident that carefully and accurately machined blocks that could be laid up with an absolute minimum of cement offered distinct, additional advantages.

Meanwhile, one of the larger steel companies, which had been using carbon brick from its controlled ceramic company with no great success, tried patching a carbon lining with a carbon paste tamped into place. The experiment was successful enough to encourage them to try a complete carbon lining installed in the same manner. As a result, a third type of carbon lining is now in use.

This last type of lining is less expensive than either of the other two, but it is relatively new and so not well proved. Both good and bad records have been made, which is to be expected from the nature of carbon. It is hard to believe that large masses of carbon of, as in the hearth, 100 tons or more, can be baked in, as it must be in the blast furnace, by the heat generated in the furnace without shrinkage cracks, for carbon in changing from the plastic to solid state does shrink up to about 2 per cent. The same situation must develop too, when a ring of paste 18 to 24 in. thick and 20 to 30 ft. in diameter bakes out as quickly as it does under blast furnace conditions. At best, the resultant carbon will be low in density and very friable, and will contain numerous cracks.

According to available information, the mass comprises good grade foundry coke ground to pass a 1 mm. (.039 in.) screen, mixed with 15–25 per cent water-free steel works tar, with preference given to the drier mixes. The mass is well mixed in steam heated mixers, and is tamped into place in thin layers by the use of hand or pneumatic rammers. The rammer heads must be kept hot while in use and the joints between fresh and previously tamped mix must be well tarred. Once the

lining of a furnace with tamped paste has been begun, it is continued until complete.

There is no need for describing the use of carbon in the standard brick sizes, for that is a mere substitution. The use of the larger blocks is a different proposition and, while more expensive than the other methods, offers the best chance for continued success. The methods now in use have been developed by trial and error over a period of years.

Two general types of construction are prevalent, one using a hearth built up of circular blocks about a truncated cone section, and the other a hearth built up of large rectangular blocks. In either method the joints are so broken that there can be no flow of metal directly downward. The blocks are very carefully and accurately machined to size and the complete lining is set up on the carbon manufacturer's testing floor, checked for dimensions, and each block numbered and marked so proper matching will be insured when installed in the customer's furnace.

When the blocks are actually installed, they do not fill the shell completely, for a space about 4 in. wide is left between the shell and the outer circumference of the blocks. As each row of blocks is set and wedged into place, the annular space is tamped full of coke braize which serves as an expansion joint, holds the blocks in place, and probably has some insulation value, thus keeping the shell that much cooler. In laying up the blocks a graphite cement is used on all surfaces, but the blocks are so tightly wedged together that the joint has no appreciable width. It will be noted in the illustrations that the tap hole blocks are ceramic, for no way of stopping air infiltration at that point has been discovered and the entering air would attack the hot carbon very rapidly.

Regardless of the type of carbon lining—that is, brick, block or paste—the lining is protected during the time the furnace is blown in (and, in the case of the paste lining, while it is baking out) by a layer of fire brick usually 4 to 5 in. thick. This protective lining does not last very long and usually is gone by the time the furnace has been tapped five times or so, but it does protect the carbon from oxidation until furnace conditions have become normal.

Perhaps the most interesting fact in connection with the use of carbon linings is that, in the portion of the furnace so lined, there are no cooling plates and all of the cooling is of the spray or shower type, on the outside of the shell. This reduces the total cost of that portion of the lining very materially and cuts down on the maintenance and operating charges. Having no cooling plates to work around, the installation of the lining is much simplified. There is really no need for cooling a carbon lining. No temperature developed in a blast furnace is high enough to have any effect on carbon, which retains all of its normal characteristics at well over 3000 degrees F. The one concern is to keep the shell itself cool enough for safety, which is most easily done by sprays.

Since neither the metal nor slag attack carbon, the hearth does not cut out at all, and blast furnace operators state that well-built hearths remain flat and there are no salamanders. This fact may be of little consequence in so far as furnace operation is concerned, but is of importance when the hearth is finally torn out for relining.

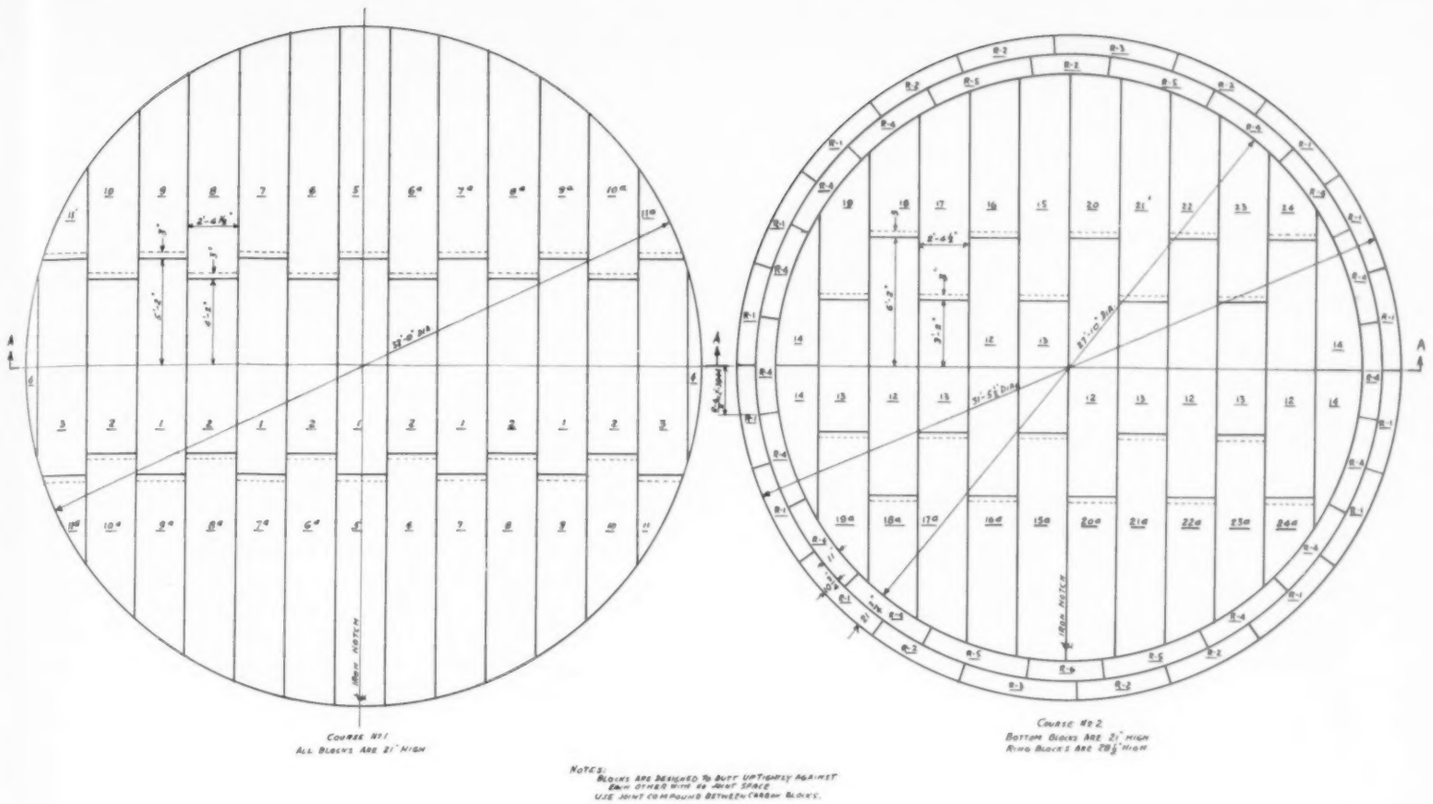
The question of lining life is a most interesting one to all blast furnace operators and the situation abroad is no different than here. In the United States it is stated that campaigns up to three million tons have been made and many of over two million tons using regular clay brick linings. Usually investigation indicates that during such long campaigns there have been extensive repairs, relining from the mantel up of from the hearth up. Presumably the reports from Germany should be listened to with a discriminating ear. Germany claims one carbon-lined furnace campaign of over three million tons and still running, and several others over two million tons in blast. The writer saw two carbon-lined furnaces in one plant that had been in service 10 years with one past two million tons and the other past 1½ million tons, and still going strong with the operators sure they were good for five to ten years more. They also stated that the only repairs had been renewal of the top of the stack. That concern had a newer furnace also with a carbon lining, and a newer one still to be blown in last April.

The question of lining cost is the most important one in the final analysis, but unfortunately the one on which the least information is available. There are two reasons for this: first, it is difficult to translate foreign costs to practice here, and second, it is difficult to compare the quality of foreign materials with corresponding materials available here. Carbon costs more than clay, and carbon blocks cost much more than clay bricks. Abroad the differential is less than here, for clay bricks cost nearly three times as much there as here—$40.00 a net ton compared with $13.00 to $14.00 for 9 in. straights. On the other hand, foreign labor costs are lower. Therefore the cost of machining the blocks is lower in Germany than would be expected here. The base wage scale is between 25¢ and 30¢ per hour with the variations for more skilled labor about in proportion to those in the United States.

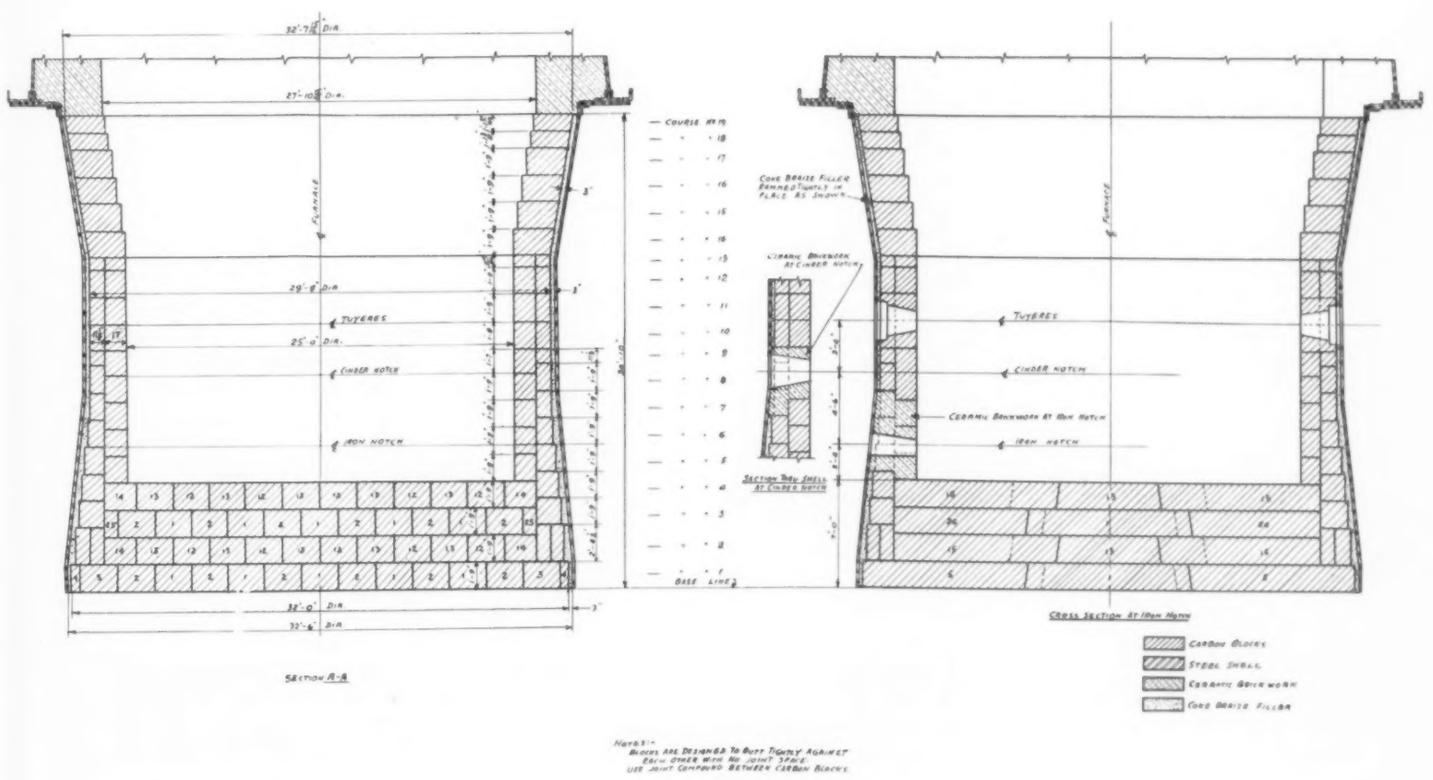
The tamped in lining is by far the cheapest type and it would seem as though if it is as good as its proponents say, it would have superseded all others, which is not the case. The cost of a tamped lining is estimated as follows for the portion of the furnace up to the mantel with a hearth lining 71–79 in. thick:

	Per long ton
Tamping paste (delivered)	$60.00
Tamping in	5.60
Fire brick lining	1.00
	$66.60

The carbon brick, no machining, cost $88.00 per long ton against $104.00 per long ton for bricks or blocks accurately machined. The difference, $16.00, is less than the cost of the machining but that price has been established over a period and is hard to change. Of course when unmachined bricks are used there is some


COURSE #1!
ALL BLOCKS ARE 21" HIGH
COURSE #0.2
BOTTOM BLOCKS ARE 21" HIGH
RING BLOCKS ARE 28½" HIGH
NOTES:
BLOCKS ARE DESIGNED TO BUTT UPTIGHTLY AGAINST
EACH OTHER WITH NO JOINT SPACE.
USE JOINT COMPOUND BETWEEN CARBON BLOCKS.

FIGURES 4 and 5—Drawings showing proposed carbon lining for a 1000-ton blast furnace with hearth diameter of 25 ft.



hand cutting to do just as with clay brick. The cost with carbon brick is estimated as follows:

	Per long ton
Carbon blocks	$ 88.00
Machining	16.00
Freight (average)	16.00
Cement	4.80
Installation	5.60
Fire brick lining	1.00
	$131.40

Freight is high for the plant manufacturing machined blocks is located close to the eastern boundary of Germany.

Installation of a machined lining, hearth to mantel, in one instance took six weeks, employing a foreman, two masons and six laborers, three of the latter getting the blocks from storage to the furnace, one running the hoist and two handling the blocks in the furnace. These men worked a ten hour day. Presumably the time could be cut in less than half by working full time. In the instance mentioned, time was of no importance, as the lining was being installed in a new furnace not due to blow in for several months.

Since no blast furnace in the United States has been carbon lined, there is nothing on which to base estimates for costs except the experience manufacturers have had in lining metallurgical furnaces which are not exactly comparable. It seems safe to state that the carbon lining of a new blast furnace up to the mantel will not cost much more than the brick lining, plus the cooling plates and piping for the same part of the furnace.

While the carbon lining offers no saving in cost installed, it does offer other possible savings. For a new furnace the construction can be simplified, for no special cooling is required. There is also a saving in the lessened maintenance charges on the simplified construction. The German operators claim much longer life for carbon linings, no salamanders, fewer runouts and many less worries.

In order that blast furnace operators may have something upon which they can work in comparing the costs of ceramic and carbon linings of a blast furnace, complete drawings have been made and from them an estimate of the cost of carbon lining a typical blast furnace up to the mantel. Figures 4 and 5 show the proposed lining as laid out to fit a 1000 ton per day furnace having a hearth diameter of 25 ft.

The hearth is made up of four layers of carbon blocks 21 in. thick making a hearth 7 ft. thick which is in accordance with German practice. The blocks are 28½ in. wide, 21 in. thick and in varying lengths as required. All surfaces of the blocks are accurately machined so the blocks can be laid up with the thinnest possible joints. All vertical joints are staggered to prevent flow of metal downward, and the horizontal flow of metal to the shell is blocked off by ring blocks set on different levels from the hearth blocks. Carbon blocks are machined to fit around the tuyeres, but the iron and cinder notches are to be ceramic lined. The lining is designed to leave 3 in. of space between it and the shell at every point, and that space is to be tamped full of coke braize to hold the blocks in place and to act as insulation. No cooling of the carbon lining is shown or required, but shower cooling of the shell will be necessary. All joints are to be laid up using the graphite paste compound which is generally used in Germany.

It is estimated that the carbon materials for such a lining will weigh before machining 1,300,000 lb. and that the finished lining will weigh 1,010,000 lb. The loss in machining is large, but it is accounted for by the fact that no carbon product can be made to size with any accuracy and that unusual allowances have to be made in producing the blocks so that they will finish machine as required. Eight thousand pounds of cement will be needed for the laying up of the blocks.

It is believed that such a lining could be installed in a furnace, for example, in the Pittsburgh district, for not over $75,000 including freight and labor of installation, and the cost might run $5,000 less than that figure. The quoted figures do not take into account any modification that might be necessary to prepare an old blast furnace for a carbon lining. In a new furnace designed for a carbon lining such changes would be made in the construction. The estimated cost should be compared not only with the cost of a brick lining up to the mantel, but to that should be added the cost of the cooling plates and the piping for them. The totals should compare favorably.

It seems hardly to be questioned that the maintenance of a carbon lined furnace will be less than a ceramic lined. The carbon lining will maintain its original thickness so the chances of loss of metal will be nil. The walls will protect the shell evenly so there should be no hot spots. There will be no cooling plates and complicated piping to keep running.

Quite a number of blast furnace operators have been giving thought to the carbon lining of blast furnaces. Several have gone further and made some studies of the situation in Germany. Unfortunately what may be erroneous conclusions may have been drawn in some cases because of lack of complete knowledge of the situation.

It should be kept in mind that there have been, and still are, three types of carbon lining used: first, the carbon brick type which offers but little advantage over the ceramic; second, the tamped-in paste lining which is relatively new; third, the carbon block type which is seemingly the most successful of all and which, from its very nature, appears to best fulfill the requirements of a trouble free, long life lining with minimum maintenance.

WHAT'LL YOU HAVE?

The parched patron probably *knows what he wants and why he wants it*, but if your wiring is kicking up trouble and you *don't know what to do about it* . . . tell us what the conditions are and we'll help you lick them with one of the one hundred and twelve standard Rockbestos heat-resisting wires, cables and cords.

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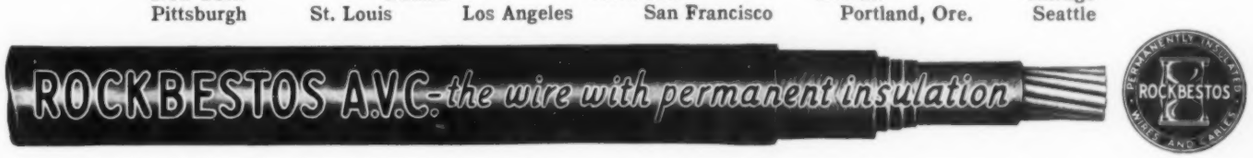


BETHLEHEM STEEL PLANS EXPANSION OF FINISHING MILLS AT LACKAWANNA WORKS

▲ Bethlehem Steel Company plans to modernize and expand the finishing mill facilities at the Lackawanna Works in Lackawanna, New York, at a cost of about $3,000,000. The program principally effects bar mill facilities and involves construction of five new buildings, each about 800 ft. long, with total floor space of nearly nine acres. The buildings will be erected south of the continuous sheet and strip mill.

The official statement released by E. F. Entwisle, general manager of the Lackawanna plant follows:

"In keeping with its policy of maintaining the producing facilities of its plants abreast of the latest developments of the steel industry and thoroughly capable of economically maintaining the quality requirements of its customers, the Bethlehem Steel Company is starting a remodeling of the bar mill facilities and making improvements in certain other departments of this plant.

"On account of the crowded conditions existing around the present three bar mill group, limiting the ability to prepare special steels for rolling and finishing, and inspection after rolling, it has been decided to remove and rebuild the old 12 in. bar mill on a new site across the main highway adjacent to the strip mill.

"No estimate of the expenditure is available as the plan will consist principally of a rebuilding operation. There will be no material change in the force required to operate the modernized mill. It is hoped that the work can be completed by the end of the present year.

"The proposed additional facilities will consist of five buildings, each about 800 ft. long, with a total floor space area of about 400,000 sq. ft. Here will be located the billet preparation and finishing equipment for the larger sizes of bars. The moving of the 12 in. mill to this location will provide finishing space for the smaller bars produced on the 10 in. and 8 in. mills, which will remain in their present location.

"One project already well under way and which should be ready for operation in July is the addition of the third 17 ton ore unloader. This will replace two of the smaller machines of the same type and will facilitate the unloading of millions of tons of ore, stone and coal that comes to the plant's dock each year.

"At the strip mill a crane runway over 800 ft. long is being built to consolidate the storage of the slabs for use at the continuous hot mill and which now are being stored at a variety of locations throughout the plant. Also at the strip mill the third of four finishing units is being equipped to produce finishing coils in addition to sheets."

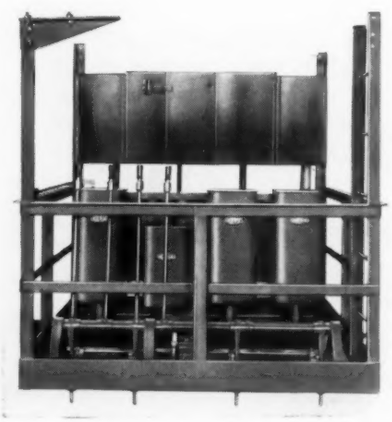
MODERN CRANE CABS ELIMINATE DANGERS

▲ New standards have been set for safety, accessibility, ease of operation and maximum vision for operators' cabs in modern overhead traveling cranes. Many cranes in industrial plants today have been in service for 10, 15, 25 years or more. However, greater safety as well as higher efficiency are easily attained by replacement of the old type cab with modern crane cabs. Manufacturers are finding that this is desirable from the standpoint of more safety and efficiency, and also because rates can be substantially decreased, owing to the safer conditions.

The economies afforded by the modern cab over the obsolete cab are many. In the old-type cab, controllers are dial type, open contact. Wiring is open, as conduit protection was then unknown. There is a single slab, open switchboard without inverse relay overload, relay protection. The operator is not protected by cabinet enclosure. The dangers to the operator as well as to the ground crew are apparent in the old-type cab. There is no foot brake, no toe angle protection, and no foot gong. Front visibility is limited because the controllers are in front of the operator.

In the modern cab the Harnischfeger Corporation has gone to great pains to correct these disadvantages, aiming at the elimination of every possible source of danger, and at the same time gaining the utmost efficiency. Drum-type controllers are fully

The modern crane cab provides the utmost efficiency, and eliminates many of the disadvantages of the old-type cab which presented a serious problem from the safety angle.



enclosed. All wiring is in conduit with junction boxes, and in accordance with underwriters' rules. The sectional panel switchboard has inverse time overload relay protection, all steel cabinet enclosure. Doors are hinged for ready access. When the door is open, the safety-type main switch is inoperative. In addition to the hydraulically-operated foot brake, there is a mechanical brake for any emergency that might arise. To guard against any slipping or falling, there is a toe angle guard of at least 6 in. height. For further protection, there is a warning foot gong. Then, too, the front operating levers are closely spaced, easy to manipulate. This provides a very convenient grouping of the operating handles, allowing the hook and load to be in constant sight of the operator.

AIR-CLEANING UNITS FOR WEIRTON PLANT

▲ Weirton Steel Company is rapidly completing the first steel mill installation of electrostatic air-cleaning apparatus for purifying ventilating air for main drives and motor-generator sets at Weirton, West Virginia. This marks the first time this new method of cleaning air has been used to protect electrical machinery from carbon, copper, and other dusts made up of minute particles that are difficult or impossible to remove with mechanical filters.

The Weirton system consists of two precipitron units, each rated at 72,000 cu. ft. per min. and involving 120 36-in. cells grouped four high by 30 wide. One smaller unit is rated at 45,000 cu. ft. per min., and is made up of 76 36-in. cells grouped four high by 19 wide. All three units operate at an efficiency of 90 per cent. These units are products of the Westinghouse Electric and Manufacturing Company.

SOUTHERN PLATE MILL INCREASES CAPACITY

▲ Republic Steel Corporation will increase their wide plate mill capacity in the Gulfsteel district, Gadsden, Alabama, by installing a slab heating furnace, making the third furnace to be installed in that district.

New buildings include a 110 by 220 ft. addition to the plate mill warehouse and a 72 by 336 ft. addition to Truscon Steel Company, a Republic subsidiary, to house a third mesh-making machine.

RENEWABLE FUSES HAVE ONLY TWO MAIN PARTS

▲ The new renewable fuses being manufactured by the Colt's Patent Fire Arms Manufacturing Company are designed for either drop-out or super-lag links. These fuses have only two main parts to assemble, the casing and strut assembly. The cap on swaged end is unscrewed, then a quarter turn of the other cap, and the

strut assembly is removed. After the link has been renewed, reverse operation assembles the fuse.

The strut of the 100 and 200 ampere sizes is made of "Vulcoid" which holds the blades in rigid alignment. The 400 and 600 sizes have struts made of heavy fibre, constructed to allow necessary adjustments.

NEW SINTERING PLANT FOR CARNEGIE-ILLINOIS

▲ Carnegie-Illinois Steel Corporation is constructing a sintering plant at the Ohio Works in Youngstown, Ohio. This plant is for the purpose of converting flue dust from the blast furnaces into sinter with a high iron content. Erection of a steel frame building has been started. The sintering machine and auxiliary equipment are to be removed here from the corporation's Joliet Works. The capacity of the plant will be 500 tons daily, and it will sinter the flue dust from current operations as well as from a huge pile of the dust, said to contain 2,000,000 tons, accumulated over many years.

NEW ROLLING MILL FOR EXPERIMENTAL PURPOSES

▲ Purdue University has recently installed a metal rolling mill for experimental purposes which incorporates a number of interesting features. This mill, which was built by Farrel-Birmingham Company, Inc., is of welded construction and is designed to perform either hot or cold rolling of metals.

It is an 8 in. x 12 in. two-high, plain-bearing rolling mill, with the mill reduction drive and pinion stand and motor mounted on a common bedplate to form an integral unit. The mill housings, drive case and bedplate are all fabricated from rolled steel plate and welded.

To permit either hot or cold rolling, two pairs of interchangeable forged steel rolls are furnished with the mill. The first pair is of suitable composition and hardness for cold rolling. The second pair, which can be substituted for the first pair, as the nature of the operation demands, is designed for hot rolling.

Housings are of the arch-top type, gas cut from steel plates. Both housings are welded into a single integral structure. Roll neck bearings are bronze, of the open, half hexagon, block type. The bottom bearings are mounted in the housing and the top bearings in steel riders. The mill is equipped with short feed and delivery tables which are made of steel plates, ground on the top surface and mounted on side brackets welded to the housings.

Mounted between the top roll rider and adjusting screw on each housing is a hydraulic cylinder or pressure block, with a ram. A two-pen recording pressure gauge, complete with pulsation dampener, is mounted on the housings on the delivery side of the mill. Pressure blocks and gauge are connected by flexible tubing and the entire system is closed and filled with glycerine, with all air excluded. The total separating force on each screw is recorded in pounds on a 12 in. diameter chart, and the separate readings for each screw are then added together, which gives the total separating force on the mill.

REPUBLIC BUILDS IRON ORE TREATMENT PLANT

▲ Republic Steel Corporation recently announced plans for construction of a small iron ore treatment plant at Spaulding mine in Birmingham, Alabama. The unit will be a pilot plant and used for large scale experimentation in improving the quality of iron ore. Iron ore in the vicinity of Grace's Gap and northward on Red Mountain which is to be treated is too siliceous to be used economically in a blast furnace for the manufacture of satisfactory iron. Republic is experimenting on a process for concentration.

Much experimental and research

work on the ore of this district has been done during the past several years by metallurgists of the section including the United States Bureau of Mines and an experimental station at the University of Alabama. The plant will be built adjacent to the tipple at the Spaulding mine.

THREE POLE BREAKER HAS NEW ARC-QUENCHER

▲ A new 600 ampere, three pole circuit breaker has been developed by the I-T-E Circuit Breaker Company. Designated as the type KB, the interrupting capacity is such, that in a dust proof enclosure it can be rated at 20,000 root mean square. A new arc-quenching device developed for this new circuit breaker is a more efficient form of the magnetic arc-quencher. Magnetic vanes, placed on the outside of insulating barriers, are magnetized with the opening of the arcing contacts, and the magnetic field thus set up forces the arc into an extinguishing chamber. Insulating barriers within the chamber cool the arc, create a turbulent gas condition and provide a cooling draft across the arc core.

The design of main and arcing contact structure of the new circuit breaker was guided by the excellent performance of the butt-type contacts developed in the type K circuit breaker. In the original breaker a single contact composed of a silver alloy highly resistant to burning was employed. This alloy has been used in the new breaker for the arcing contact. This change permits the use of silver blocks for the main contacts.

The original type K circuit breaker was designed for electrical operation only, and the solenoid operating mechanism was mounted on the left hand side of the contact structure. This construction did not provide for manual operation or for a combination of electrical operation and manual operation. In the new circuit breaker, the solenoid mechanism has been moved from the side of the frame to the front of the device directly beneath the contact structure. This saves considerable width and affords direct mechanical action to the center of the operating arm. At the same time, the new arrangement provides for emergency hand operation on the electrically operated device. The fact that the solenoid mechanism is an attachment on the base of the frame makes it possible to furnish this same circuit breaker manually operated. The electrical and manual operation are obtained in such a way as to get a trip free device throughout the closing stroke.

PRECISION BEARINGS IN DIMINUTIVE SIZES

▲ Diminutive size precision ball bearings down to $\frac{1}{8}$ in. in bore, which heretofore have been available in the "full" (retainerless) type, can now be obtained as standard with retainers (or ball cages). These bearings are manufactured by the Norma-Hoffmann Bearings Corporation, the pioneer in the manufacture of this type of bearing. The bearing with an $\frac{1}{8}$ in. bore has an outside diameter of $\frac{3}{8}$ in. and a width of $\frac{5}{32}$ in.

WIRE COMPANY PLANS PLANT MODERNIZATION

▲ American Steel and Wire Company will spend about $520,000 for modernization of its wire drawing facilities at Donora, Pennsylvania. Work is

REGISTERS DRAFT,
PRESSURE
AND
DIFFERENTIAL
in
SOAKING PITS
●
ANNEALING FURNACES
●
OPEN HEARTHS
●
SLAB MILLS
HAYS "OT" DRAFT
RECORDER
Results in a better product because it gives a correct indication of furnace atmospheres. Built husky enough to stand the severest steel mill conditions yet sensitive enough to register accurately in increments of .0025 in. water. Employs the famous Hays Slack Leather Diaphragm—self sealing—not damaged under sudden excess pressures. Two draft values, two pressure values, two differential values, or a combination of any two of these three values may be recorded. Or a temperature recorder may be substituted for one of these values. Send for descriptive literature. Write to 955 Eighth Avenue, Michigan City, Indiana.
The HAYS CORPORATION
SINCE 1901
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

scheduled to begin soon and will require about six months for completion.

Steam operated equipment in the wire drawing department will be replaced by new electrically operated wire drawing machinery and auxiliary equipment. Some of the outmoded machinery is 35 years old. It is understood the work will be done without completely shutting down the plant.

FLOW METER INTEGRAL PART OF PIPE LINE

▲ A new type of meter, the "Linameter," has been introduced by the Cochrane Corporation. This meter is adapted particularly to the measurement of fluids having characteristics of viscosity, corrosiveness, and solubility such as fuel oil, ammonia, hot tar, etc., which are beyond the scope of the conventional orifice type flow meter.

This new meter is of the area type, with meter body installed as an integral part of the pipe line, and containing a weighted disk positioned by the velocity of fluid through a tapered throat section in such a manner that the disk travel is directly proportional to flow rate. Attached to the weighted disk is a rod and iron core, the latter of which traverses the field of two reactance coils surrounding the pressure tight tube of the meter body. These coils form a reactance bridge when connected electrically to similar coils in the indicating, recording and integrating instrument and form the means of transmitting the measurement to any desired distance from the meter body. Measurement is accomplished in the recording instrument by use of the galvanometer null principle, as applied to the electric flow meter.

NEW LIVE CENTER FOR MANY TYPES OF WORK

▲ Ideal Commutator Dresser Company has developed a new live center with interchangeable inserts or center pieces for holding centered and uncentered work. Three inserts are available and may be used interchangeably depending upon the work to be centered: (1) male insert—for work already centered; (2) plain female insert—for uncentered work, *i.e.*, armature, drills, etc.; (3) female insert with three raised lands for uncentered work having a flat or burred keyway. Inserts are quickly removed by knockout screw.

All parts of the live center are hardened and ground. Only highest precision bearings obtainable are used. A short overhand eliminated chatter. All cuttings, oil, dirt and chips are kept out by sealed ball bearings.

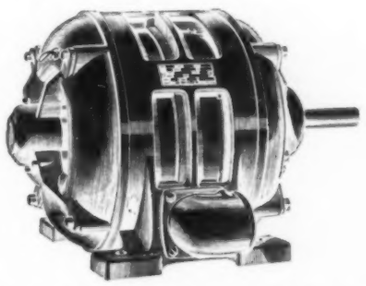
Manufactured to highest precision standards, the center is adaptable to an endless variety of centered and uncentered work.

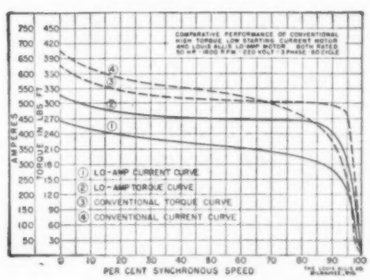
LOWER LOCKED CURRENT IN NEW MOTOR DESIGN

▲ For many years users and power companies alike have been searching for a motor with a lower locked current than seemed possible with the simple squirrel cage motor. Not being able to obtain such a motor, users have been compelled to use complicated commutator or relay type machines and in many cases, expensive multi-step starters.

The new "Lo-Amp" motor manufactured by the Louis Allis Company is designed to solve these problems. The outstanding features and advantages of this new motor are: simple rugged squirrel cage construction; no centrifugal switches; no relays; no brushes; no slip rings; no wound rotors; smoother acceleration; and special controls are not necessary.

This new motor is designed to solve the problems of those motor users who need a motor with a lower locked current.




COMPARATIVE PERFORMANCE OF CONVENTIONAL HIGH TORQUE LOW STARTING CURRENT MOTOR AND LOUIS ALLIS LO-AMP MOTOR BOTH RATED 50 HP., 1800 R.P.M., 220 VOLT, 3 PHASE, 60 CYCLE
AMPERES
PER CENT FULL LOAD TORQUE
PER CENT SYNCHRONOUS SPEED
① LO-AMP CURRENT CURVE
② LO-AMP TORQUE CURVE
③ CONVENTIONAL TORQUE CURVE
④ CONVENTIONAL CURRENT CURVE

CARRIE FURNACES TO INCREASE CAPACITY

▲ Carnegie-Illinois Steel Corporation will completely rebuild from the foundation up, No. 3 blast furnace at the Carrie Furnaces, Rankin, Pennsylvania. The rebuilt unit will have an average daily capacity of approximately 1,100 net tons, an increase over the old unit which was last rebuilt in 1927. Provision has also been made for improved gas washing equipment. The company at present is modernizing one of its furnaces at its Edgar Thomson Works and will soon begin a similar program on another furnace there.

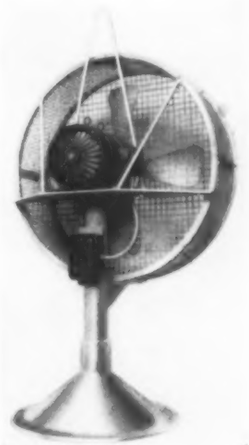
CANADIAN PLANT BUILDS FOUR-HIGH PLATE MILL

▲ Steel Company of Canada, Ltd., recently approved plans for the construction of a 4-high mill for production of plates, at Hamilton, Ontario. Contracts for the equipment will be let as soon as possible. The new mill is to be installed with the intention that at some future time it will become a part of the roughing train of a 4-high continuous strip mill. Consulting and engineering service is under the direction of C. H. Hunt, consulting engineer of Pittsburgh, Pennsylvania.

COOLING FANS IMPROVE WORKING CONDITIONS

▲ A new series of portable man cooling fans, available in sizes ranging from 12 in. to 36 in. in diameter, has been announced by the Truflo Fan Company.

The 36 in. man cooling fan is 48 in. high to center line of fan wheel, and



has a 32 in. diameter cast iron base and 4 in. pipe stand. A special ¾ in. round steel bar is electrically welded to motor base and bolted to top of guard for handling with overhead crane. This fan employs a 3 hp. motor, 60 cycle a-c. at 1150 rpm. The total weight of the stand, guard and propellor, a 4-blade solid cast aluminum wheel, is 356 lb.

In addition to man cooling, these fans may be used for improving working conditions in all types of occupations. These fans are sturdily constructed for hard usage and are so designed that the flow of air does not necessarily play directly on worker. Drafts are eliminated and cool, comfortable working temperatures are maintained, resulting in lowered humidities, improved efficiency and better working conditions.

POLISHING MACHINE FOR BUFFING AND COLORING

▲ A polishing machine for light buffing and coloring to take the place of heavier machines for the same work has been developed by the Lewis Roe Manufacturing Company. The machine consists of a head and stand and is driven by a ¼ hp. a-c. or d-c. motor which is mounted on the stand.

The machine is equipped with two self-aligning ball bearings and has a ¾ in. spindle 22 in. long. Longer spindles can be furnished if required. The spindles are turned down at the ends to ½ in. and threaded eight square threads to the inch. The ends in spindle are tapped for taper points which are furnished with machine. A V-belt and a device for keeping belt at a uniform tension is also furnished. The motor has 8 ft. of cord and a switch. Machine weighs approximately 100 lb. and the power consumption is approximately one cent per hour. It is very efficient for light work and is also portable.

U. S. STEEL TO BUILD MORE TIN PLATE UNITS

▲ United States Steel Corporation, which recently announced a program for increase in tin plate capacity at the Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama, will increase the facilities for making cold reduced tin plate in the Pittsburgh and Chicago areas, it has been announced.

Carnegie-Illinois Steel Corporation is inaugurating a program of rounding out and balancing facilities for the production of cold reduced tin plate in the districts named above. No estimate of the cost of the improvements is available, but it is believed that they will total several million dollars. The program for the Pittsburgh district calls for the installation of another five-stand tandem 42 in. cold reduction mill and processing equipment to increase the production of cold reduced tin plate at the Irvin Works. In the Chicago district, the program provides for the installation of additional processing and finishing equipment at the Gary sheet and tin division.

Two 15-ton-100'-0" span Cleveland *all-welded* steel-mill cranes operating over continuous pickling lines.

WHERE UNINTERRUPTED CRANE SERVICE IS VITAL, PLAY SAFE WITH

CLEVELAND *all-welded* CRANES

In the big mills, on the jobs where crane service is vital, many Cleveland all-weldeds will be found because they can be depended upon to carry through peak loads without interruption.

You, too, will find it profitable to install Clevelands at those places where crane service *must* be available.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

PROGRESS SHOWN IN AIR FILTER DESIGN

▲The new "Protectomotor" air filter recently announced by the Staynew Filter Corporation is primarily designed for the complete removal of the slightest traces of oil from compressed air lines. In addition, it effectively prevents the passage of moisture as well as dust, dirt, pipe scale or other foreign matter commonly found in pipe lines for air supply. The main feature of the new filter is a series of discs possessing a large absorption area plus unusual filtering efficiency. These discs are made of an exclusive felt-like material used in most Staynew air filters. The discs are carried on a tube composed of an inner liner of perforated metal covered with a fine bronze wire mesh screen. This tube helps to drain oil removed from the air to the bottom of the filter shell.

A wide range of pipe sizes and filter capacities is available, ranging from ¼ in. pipe size for filter of 5 cu. ft. per min. capacity to 2 in. pipe size for filter of 100 cu. ft. per min.

NEW LITERATURE

▲ Blaw-Knox Company has prepared a 40-page catalogue (No. 1696) on buckets for single drum hoists. The types of buckets described include: Single line hook-on clamshells; single line direct reeved type clamshells; extremely low head room hook-on type clamshells; single and two line ship's tackle clamshells; two line hook-on type clamshells; dump buckets of the tip-over type; bottom dump buckets; and ingot tongs. Copies of the catalogue, which also contains service hints and application data, may be obtained by writing the Blaw-Knox Company, Pittsburgh, Pennsylvania.

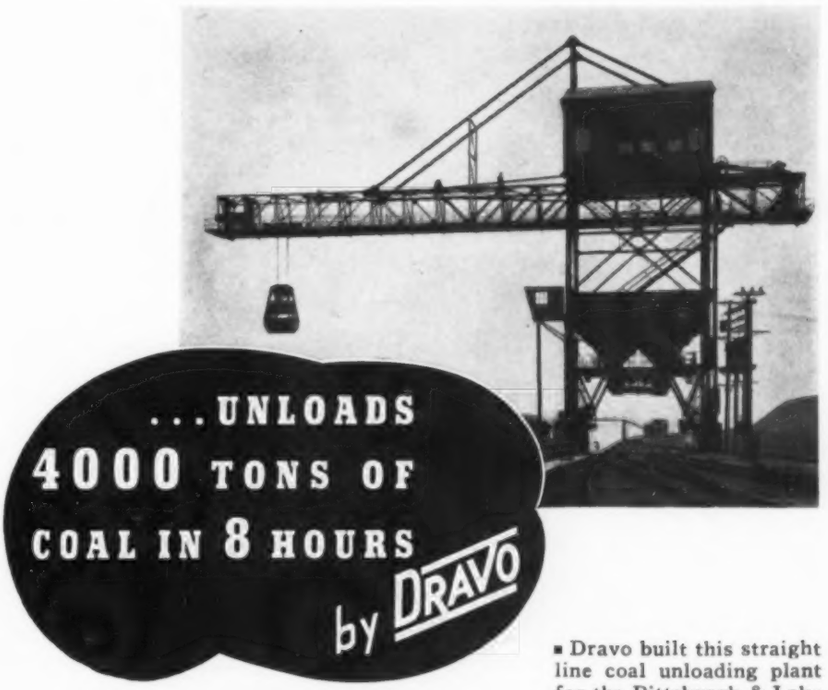
▲ Mesta Machine Company has available a booklet describing "Mesta Roll Grinders." These grinders were originally developed for use in Mesta shops, where fourteen grinders are in operation, but their splendid performance soon brought them to the attention of roll users. This gave further opportunity to study grinders operating under actual mill roll shop conditions. The book is amply illustrated and contains technical description of sizes and types of grinders for the industry.

Individuals desiring copies should write to the Mesta Machine Company, P. O. Box 1466, Pittsburgh, Pennsylvania.

▲ Leeds and Northrup Company has available for distribution a book on "Blast Furnace Temperatures—Recorded-Controlled by Micromax." This book contains a complete line of temperature measuring and controlling equipment for blast furnace operation. Copies may be obtained by writing the Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia, Pennsylvania.

▲ De Laval Steam Turbine Company has available copies of a technical article entitled: "Automatic Priming Systems for Centrifugal Pumps." This article describes an automatic priming system which keeps the centrifugal pump always filled with water and eliminates need for attention from operators. Special applications are described for individual pumps, a group of pumps using a common suction main, deep well pumps, sewage pumps, and other types of pumps.

This article may be obtained by



▪ Dravo built this straight line coal unloading plant for the Pittsburgh & Lake Erie Railroad Company. A 7-ton bucket with fast travel handles 4000 tons in 8 hours from barge to cars. It has a free digging capacity of 7000 tons per hour. Two barges abreast can be unloaded at the same time, and, although the plant is stationary, the operator can move the barges along as unloading progresses. He does this by means of a shifting device controlled from his cab. And finally, it more than satisfies its owners.

Whether the problem is one of modernizing old equipment, replacing obsolete handling machines or designing special facilities to meet new problems, consultation with Dravo Corporation may prove to be of great value to you. Added to its ability to fabricate and erect structures as shown above, Dravo Corporation has had years of experience building docks, retaining walls, plant foundations—everything that enters into the problem of terminal facilities. Bulletin 403 describes docks, mill foundations and terminal equipment. Bulletin 202 describes revolving cranes. Either will be sent upon request. Inquiries relative to specific problems may be addressed to

DRAVO CORPORATION
ENGINEERING WORKS DIVISION

SHIPYARDS: PITTSBURGH, PA.—WILMINGTON, DEL.
GENERAL OFFICES AND SHOPS: NEVILLE ISLAND—PITTSBURGH, PA.

addressing the De Laval Steam Turbine Company, Trenton, New Jersey.

▲ Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania, has available the following bulletins:

Bulletin F-8583 which describes the new steel mill contactors designed for heavy duty d-c. mill and crane applications, where special protection against service interruption is essential.

Descriptive Date Booklet DD-36-116 features the new indoor disconnecting switches, giving complete details of construction and application of the switches. These switches are available in ratings of from 20 to 600 amperes for 5,000 volt service and 400 to 6,000 amperes for 7,500 to 34,500 volt service.

Catalogue section 29-460 describing the "Nofuze De-ion" circuit breaker panelboards, designed particularly for use where the air is filled with chemical or acid vapors and calibrated for use under oil. These panelboards are suitable for both indoor and outdoor mounting, and the new thermal-trip breaker insures constant tripping regardless of temperature change.

▲ Trico Fuse Manufacturing Company has issued a folder entitled: "14 Big Trouble Savers." This folder contains complete specifications and illustrations of powder-packed renewable fuses, non-renewable fuses, plug fuses, thermal time-lag plug fuses, tamper resisting plug fuses, clamps for locking fuse clips, heavy-duty test clamps, fuse pullers and automatic lubricators for all types of bearing surfaces.

Trico Fuse Manufacturing Company is located in Milwaukee, Wisconsin.

▲ Combustion Engineering Company, Inc., has published a booklet entitled: "Elesco Superheaters." Details of construction of both the ball-joint and the welded types are covered and numerous diagrams show various arrangements for application to different types of boilers and to meet different conditions.

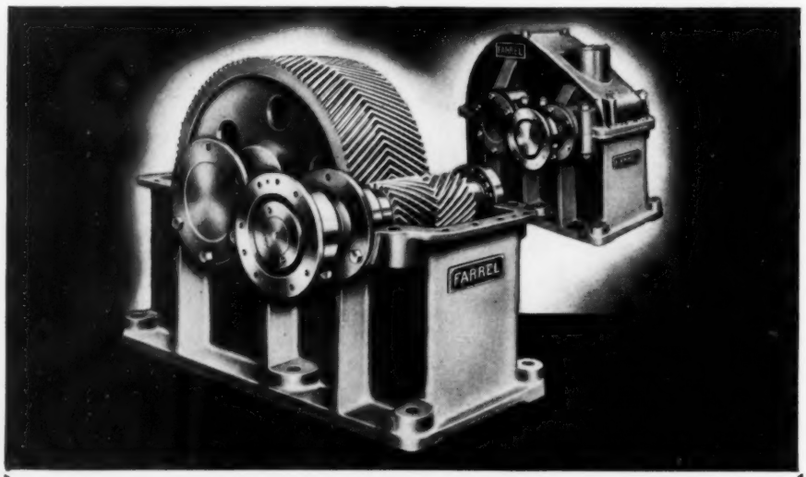
Please write direct to the Combustion Engineering Company, Inc., 200 Madison Avenue, New York, New York.

▲ Edison Storage Battery Division of Thomas A. Edison, Inc., has published a monograph for the use of industrial science and engineering schools. This monograph, originally issued in 1916 at the invitation of the Joint Committee on Physics as an aid to instruction in industrial storage battery practice, has been completely rewritten. The text has been brought fully up-to-date with latest developments in the uses of storage battery power by industry, and much new material has been added.

Write to the Edison Storage Battery Division of Thomas A. Edison, Inc., West Orange, New Jersey, for copies of this brochure.

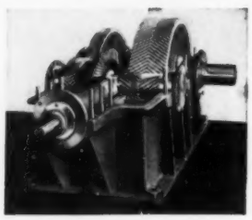
▲ Allis-Chalmers Manufacturing Company now has ready a revised General Texrope Catalogue section, No. 151, introducing new horsepower ratings for multiple V-belt drives. It provides engineering information on selection of size of belt for horsepower rating, speed, center distances and sheave diameters.

If you desire to obtain this catalogue section, address Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.



Farrel Single Reduction Unit—Type SR

FARREL GEAR UNITS



Farrel Right-Angle Two-Speed Gear Unit

This catalog, No. 438, gives complete descriptions, specifications, ratings and dimensions. Send for free copy.

Perform Dependably and Economically under all Conditions of Service..

The greater strength and load-carrying capacity of Farrel-Sykes continuous tooth herringbone gears are important factors in the durability and efficiency of Farrel Gear Units. The rigidity of their heavy cases eliminates deflection and vibration. Operation is smooth and quiet. They give silent, positive, uniform transmission of power.

The complete series of these units includes single, double and triple reduction units, speed change units with two or more selective speeds, right angle units and drives to suit special needs. Speed increasing units are also supplied. All offer the advantages of standardized general design, with flexibility in detail which permits variation to suit specific conditions of speed, load and service.

FARREL-BIRMINGHAM COMPANY, INC.
366 VULCAN STREET BUFFALO, N. Y

FARREL SYKES GEARS — The Gear with a Backbone

ITEMS OF INTEREST

Hugh G. Gibson has been appointed general superintendent in charge of all operations of the tin plate division of the McKeesport Tin Plate Corporation, McKeesport, Pennsylvania. Mr. Gibson, who received his engineering training at Carnegie Institute of Technology, joined the McKeesport Tin Plate Corporation in 1927 as master mechanic and has since held the positions of chief engineer, assistant superintendent and acting general superintendent.

Prior to going with McKeesport Tin Plate Corporation, he was a construction engineer for the Aetna Foundry and Machine Company and supervised, among other projects, the installation of new machinery in the hot mills and the tin house of McKeesport Tin Plate Corporation. His first connection with the tin plate industry was in 1923 when he joined the engineering department of the American Sheet and Tin Plate Company at New Castle, Pennsylvania.

Mr. Gibson was born in Erie, Pennsylvania, in 1901. He is an Active Member of the Association of Iron and Steel Engineers.

James W. Corey, since 1932 general sales manager of the Reliance Electric and Engineering Company, Cleveland, Ohio, has been elected vice-president in charge of sales. Mr. Corey started in the engineering department of the company in 1911, and was transferred to the sales department in 1916. He was made assistant sales manager in 1927 and general sales manager five years later. He has been a director of the company since 1935.

Robert S. Crawford has been appointed superintendent of rolls, Timken Roller Bearing Company, Canton, Ohio, assisting Gene Ball, superintendent of rolling mills. Mr. Crawford began work as an apprentice in the American Steel and Wire Company in 1915, and remained there until 1918. After serving in the army during the World War, he joined the Bourne-Fuller Company. The following year he became roll foreman of the Republic Steel Corporation, Cleveland, Ohio. From this position he was promoted successively to roll designer and roll engineer.

Lee D. Harmony has been appointed sales manager of the Streine Tool and Manufacturing Company of New Bremen, Ohio. Mr. Harmony went to this company in 1928 as cost accountant and has been purchasing agent for the past ten years.

George C. Floyd, superintendent of the alloy strip department of the West Leechburg division of the Allegheny-Ludlum Steel Corporation, Brackenridge, Pennsylvania, has been appointed assistant general superintendent of that division.

Joe E. Kiefer, chief engineer, Streine Tool and Manufacturing Company for the past four years, will also assume charge of all sales engineering for the company. Mr. Kiefer is a graduate engineer from Ohio State University and is well qualified for his added duties.

James G. Davey, formerly divisional superintendent, stainless sheet and strip division, Republic Steel Corporation, was made plant manager of the Eastern Rolling Mill Company, Baltimore, Maryland.

Vernon E. Piez, now affiliated with the American Car and Foundry Company as a sales engineer in the valve division, was for eighteen years associated with the Walworth Company in various capacities including production and sales development.

Mr. Piez has been transferred to the midwest states where he will devote much of his time to the iron and steel industries for the American Car and Foundry Company. His headquarters office will be at 30 Church Street, New York, New York.

J. H. Morrison, superintendent of blooming and rod mills of the Pittsburgh Steel Com-

JAMES W. COREY

LEE D. HARMONY

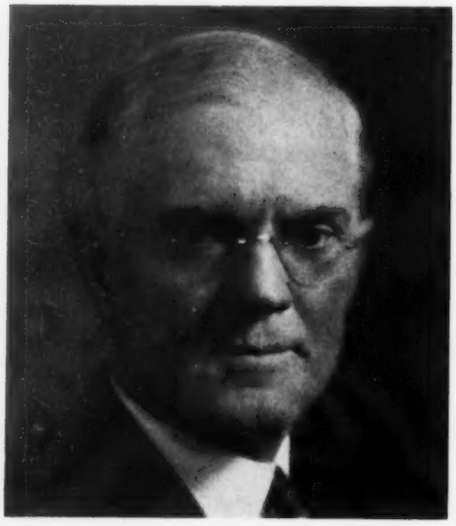
JOE E. KIEFER

pany, Monessen, Pennsylvania, has been made superintendent of all hot rolling operations at the company's Monessen and Allenport plants.

Edward S. Perot was elected president of the Crocker-Wheeler Electric Manufacturing Company of Ampere, New Jersey. Mr. Perot was employed nine years by the National Conduit and Cable Company, serving two years as vice-president. For three years he was president of Dictograph Products Company, and six years president of Southern Dairies, Inc. He joined Crocker-Wheeler early in 1939 as executive vice-president, and was elected to the board of directors in June of that year.

L. N. McDonald, general superintendent of the Youngstown, Ohio, district operations of Carnegie-Illinois Steel Corporation, will retire May 1, upon completion of 55 years of service with subsidiaries of United States Steel Corporation.

Mr. McDonald was first employed by Carnegie Steel Company at the Edgar Thomson Works, Braddock, Pennsylvania, in 1885. He transferred to the Duquesne Works in 1890 and worked in blast furnace operation there for 12 years. He was transferred to Ohio Works in Youngstown as superintendent of the Bessemer department in 1902, and six years later was given supervision of both the Bessemer and open hearth departments. Mr. McDonald was assistant general superintendent of the Youngstown district works from 1916 to 1925. He was appointed general superintendent March 1, 1925, and has continued in that capacity to date.



L. N. McDONALD

A. W. Krowell was appointed superintendent of production for the Carnegie-Illinois Steel Corporation's Gary Works. Mr. Krowell was first employed at Gary Works in 1915 as a marker in the merchant mill. He served at this mill in various capacities until 1920 when he was made general finishing end foreman of the 160 in. plate mill. In 1925 he was given the same post at the 60 in. plate mill and after remaining in this position for nine years, he was appointed finishing end foreman of the plate mills. A short time later he was made chief shipper and in 1937 he became assistant superintendent of the production department, the position he held until the present time.

Ralph D. Peterson has been appointed assistant superintendent of production at the Carnegie-Illinois Steel Corporation's Gary Works. Mr. Peterson came to the Gary Works in 1912 as a painter in the plate mill. He was continuously employed in the plate mills until 1939 when he received the position of chief provider for the slab and plate mills, the post he held at the time of his appointment. During his employment at Gary, Mr. Peterson also served as assistant provider, provider, mill foreman, and steel provider.

W. J. Huge was appointed assistant to superintendent of blast furnaces, Carnegie-Illinois Steel Corporation, Gary Works. Mr. Huge began at the Gary Works as a blower in the blast furnace department in 1912, after four years of general furnace practice at South Works. Remaining here a short time, he left Gary to return again in 1928 as assistant superintendent of blast furnaces No. 7 to No. 12. He served in this capacity and as a metallurgist until this recent appointment.

Edwin A. Dawson was appointed superintendent of the rod mill for the Pittsburgh Steel Company at their Monessen, Pennsylvania, plant.

W. C. Kitto, formerly superintendent of the open hearth department at the Monessen, Pennsylvania, plant of the Pittsburgh Steel Company, has been made superintendent of the open hearth and blooming mil.

A. C. Cummins has been appointed general superintendent of the Youngstown district operations of Carnegie-Illinois Steel Corporation, succeeding L. N. McDonald, who will retire upon completion of 55 years of service with subsidiaries of the United States Steel Corporation.

Mr. Cummins, a graduate of Lehigh University, has been associated with Carnegie-Illinois and the former Carnegie Steel Company since 1911 when he was employed as an electrical draftsman at the Duquesne, Pennsylvania, Works. He served in various engineering, construction and operating capacities at Duquesne Works for several years, and in 1919 was named superintendent of the electrical department. He was appointed assistant general superintendent of the plant in 1932 and a year later became general superintendent. Mr. Cummins has been assistant manager of Pittsburgh district operations of Carnegie-Illinois Steel Corporation since August 1, 1936.

An Active Member of the Association of Iron and Steel Engineers since 1919, Mr. Cummins is a Past President and at the present is an Honorary Director.

Frank A. Garvey, assistant superintendent of the Union Drawn division of Republic Steel Corporation, Cleveland, Ohio, has been promoted to superintendent of that division. Mr. Garvey joined the Union Drawn division in 1936, after having served as an industrial engineer and production executive in both the automotive and machine tool industries for 15 years.

Obituary

George Harris, 94, pioneer resident of Niles, Ohio, and early connected with the iron and steel industry in the Mahoning and Shenango valleys, died recently in Niles, Ohio. Mr. Harris was born November 3, 1845, in England, his parents bringing him to the United States the following year. He obtained his first job in his father's mill at Niles, and later was superintendent of the American Tin Plate mill at Sharon, Pennsylvania, devoting 40 years of his life to rolling mill work.

Peter H. Nebe, 78, one of the pioneers of tin plate production, died recently in Gary, Indiana. Mr. Nebe held his first position as tin house foreman in the old Demmler Works at McKeesport, Pennsylvania. In 1910, Mr. Nebe moved to Illinois where he worked as tin house superintendent for the Granite City Steel Company, until his retirement in 1920.

Howard B. Loxterman, 57, a vice-president and director of the Blaw-Knox Company, died recently following an extended illness. Mr. Loxterman was connected with the Blaw-Knox Company since its formation 34 years ago. Entering the drafting department in 1906, he was soon placed in charge of design and fabrication of steel forms. His next advancement was as manager of service, following which he was appointed sales manager of the Blaw-Knox division. He was elected secretary and director of the company in 1934, and in the same year was elected a vice-president.

Thomas Weiskopf, 57, superintendent, Union Drawn Steel division of Republic Steel Corporation, Massillon, Ohio, died recently. Mr. Weiskopf, who has been with that company since 1903, transferred to Massillon eight years ago from Beaver Falls, Pennsylvania, where he was superintendent of the company's plant.

William W. Leopold, 38, general superintendent of the Superior Sheet Steel Company division of Continental Steel Corporation, Canton, Ohio, died recently as a result of injuries suffered in an automobile accident. Mr. Leopold, a native of Canton, Ohio, started as heater's helper with the Superior Sheet Steel Company, when it began operations in 1920. In 1939 he was appointed general superintendent in charge of production.

Martin H. Welch, superintendent of a blast furnace shift at Ford Motor Company's Rouge Works, died recently. Born in Youngstown on November 10, 1867, Mr. Welch became known widely as first operator of a blast furnace for 100 per cent Mesabi iron range ore and is credited with markedly increasing the possible daily output of iron. He went to Detroit in 1920 to work for the Ford Motor Company.

J. E. Hughes, 46, sales engineer for the Aetna-Standard Engineering Company, Youngstown, Ohio, died recently. Mr. Hughes went to Aetna-Standard in May, 1931.

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